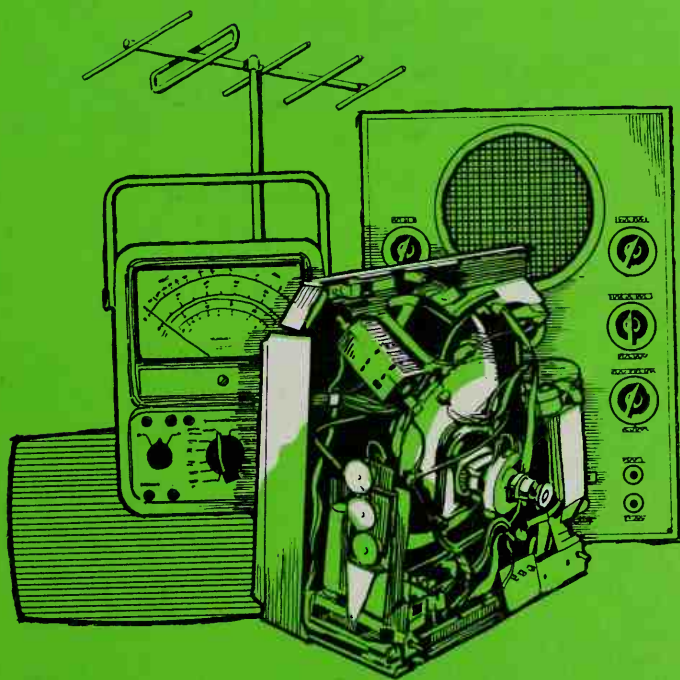# TELEVISION
SERVICE MANUAL

by Robert G. Middleton

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TELEVISION
SERVICE
MANUAL

by Robert G. Middleton

FOURTH EDITION

Fourth Printing—1982

Foreword

The previous editions of this work have been widely used by students, TV servicemen, and electronic technicians all over the world.

This edition has been completely revised and updated to reflect the present state of the art. Planned as an all-inclusive volume, it encompasses the entire scope of video transmission and reception, providing a comprehensive coverage of system and circuit theory, system standards, installation and maintenance procedures.

Today, semiconductor circuitry is in wide use. Some black-and-white and color TV receivers are of the hybrid type, and employ both tubes and transistors. Other receivers are transistorized throughout (with the exception of the picture tube). Integrated circuitry has made inroads on conventional transistor circuitry, and new types of semiconductors such as the field-effect transistor and the silicon controlled rectifier must now be contended with at the service bench. Therefore, detailed explanation of these topics has been included in this new edition.

Considerable space has been devoted to antenna arrays, transmission lines, and antenna system design and installation. Color television is also dealt with in considerable detail, concentrating on those circuits which have no counterparts in monochrome receivers.

Thus, this updated edition will serve as a complete study and reference handbook of value to anyone needing knowledge of television, particularly those interested in the repair of receivers.

Contents

chronization—the color signal—luminance signal—chrominance signal—color-receiver circuits—RF tuner—video-IF amplifiers video detector—sound IF and audio sections—video amplifier— the AGC circuit—the sync circuits—vertical sweep—horizontal sweep—bandpass amplifier—color synchronization—color killer the matrix and demodulator section—characteristics of the three-beam picture tube—transistor color-TV receivers—summary—review questions

CHAPTER 15

CHAPTER 16

Television Broadcasting

The word "television" is made up of two parts—*tele* from the Greek word which means "far," and *vision* which means "to see." Thus, television means "seeing from a distance." As used today, the word means "the transmission and reception of moving visible images so that at a distant receiver the likeness of the original scene can be viewed."

GENERAL

In television, as in radio broadcasting, the signals are transmitted through space by means of radio carrier waves, as shown in Fig. 1. Basically, there is little difference between a television receiver and a common radio receiver. In the radio system, the sound is first converted to an electrical signal which is transmitted to a distant point. The sound is then converted to a mechanical motion that drives a speaker which, in turn, produces audible sound waves. In the television system, the light signals are converted to an electrical signal which is transmitted to a distant point and then converted to a light signal.

In radio, we are concerned with only one signal—that of the music, speech, etc. being transmitted. In television, the situation is far more complicated. In order to display a picture and to reproduce the accompanying sound, several separate signals must be transmitted. Each of these signals will be discussed later in this chapter.

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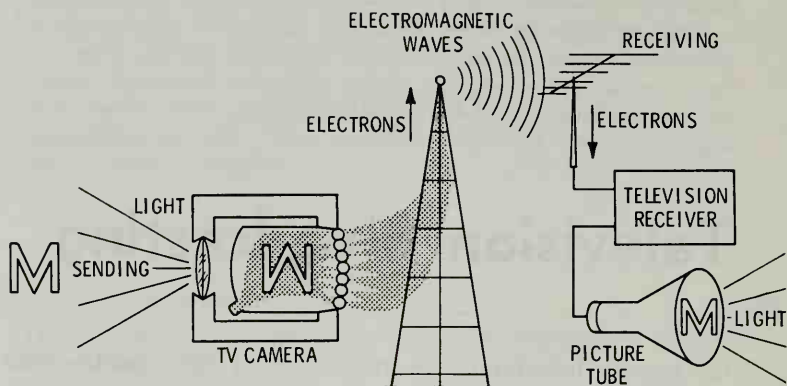
Fig. 1. Television signals travel through space as electromagnetic waves.

A simplified block diagram of a complete television system is given in Fig. 2. The image is picked up by the camera, and and electrical signal corresponding to the image is developed. This signal is then properly shaped, amplified and transmitted to the receiver. At the receiver, the signal is amplified and properly synchronized, so that a reproduction of the original image is displayed on the picture tube. For simplicity, the sound circuits are omitted in Fig. 2. Chart 1 shows how the sound section can be considered separately from the picture section.

THE SCANNING SYSTEM

Since no method by which the entire picture can be transmitted simultaneously is feasible with our present knowledge, a different system of transmitting the picture must be employed. This system is known as scanning. In the camera, the scene is focused on a light-sensitive area by an optical lens system. The optical image forms an electric charge corresponding to the light image. This charge pattern is scanned by an electron beam which moves across from side to side and from top to bottom at a rate set by

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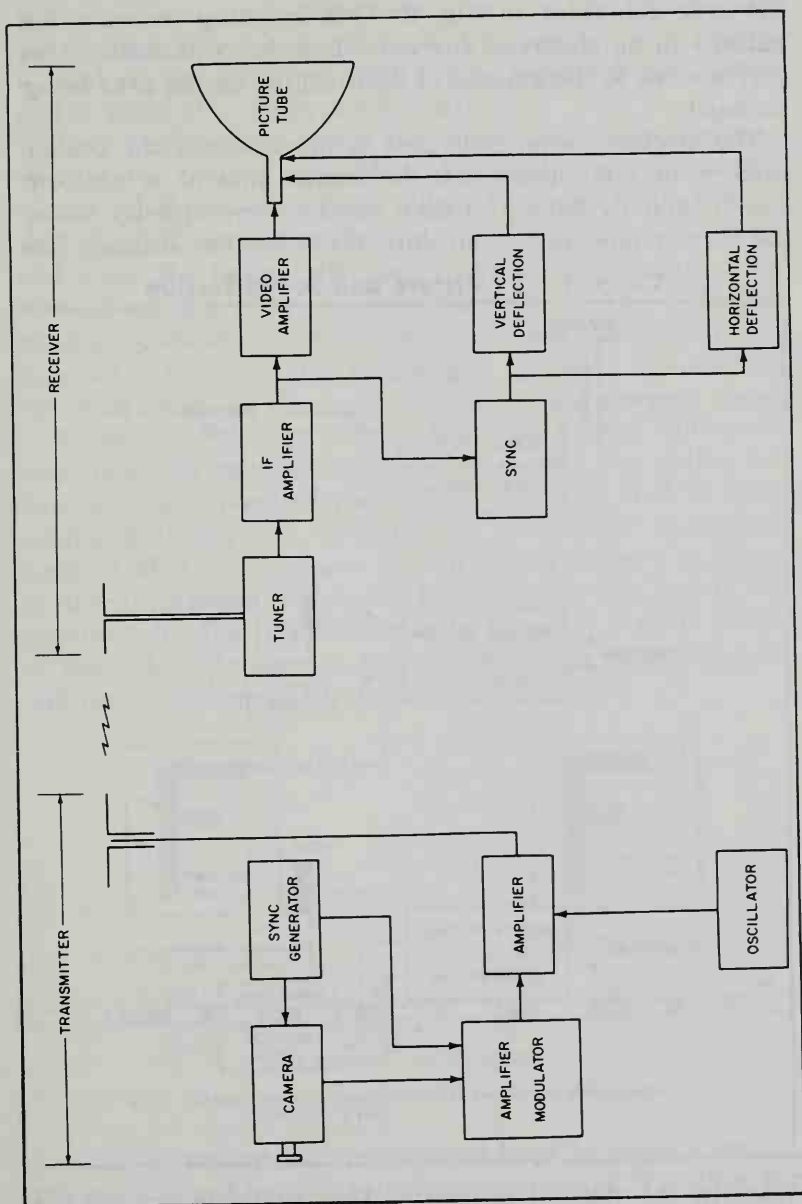
Fig. 2. Simplified diagram of the complete television system.

TELEVISION BROADCASTING

the sync generator in Fig. 2. This scanning converts the pattern in an electrical current whose instantaneous value corresponds to the amount of light falling on the area being scanned.

The electron beam is caused to move across the charge pattern in an approximate horizontal line at a uniform speed, then fly back and scan another line directly below the former one, and so on until the beam has scanned 525

Chart 1.   TV Picture and Sound Section
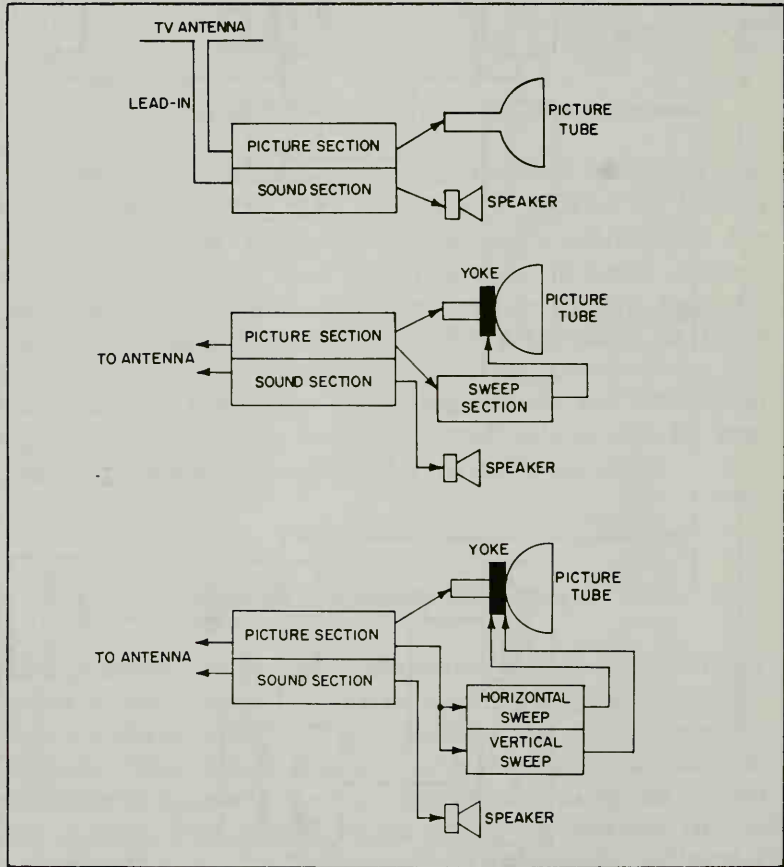
lines in the desired sequence. This complete scanning is repeated at the rate of 30 frames per second. Thus, in

modern television systems, scanning consists of 525 horizontal lines, which are covered 30 times per second, making a total of 525×30 or 15,750 lines scanned per second, and 60 fields (two fields per frame).

When the electron beam falls upon an illuminated portion of the mosaic, current will flow through the output circuit of the camera tube. When the beam falls upon a partially illuminated portion, a smaller current will flow; and when the beam falls upon a dark portion, very little current will flow. This process is depicted in Fig. 3. In this manner, current pulses will be generated which will correspond in time sequence to the light and dark areas of the televised image as they are scanned by the electron beam.

When this scanning process takes place at a sufficiently high rate, the eye is deceived into "seeing" the entire picture at once even though a small dot is all that is being produced at any one instant. This "deceiving" is possible because of a phenomenon known as *persistence of vision* of the human eye. When the beam strikes the face of the picture tube, the face continues to glow for a short period of time. Also, because of the persistence of vision, the eye will retain this image for a short period of time.

(A) Pattern to be scanned.   (B) Scanning sequence.

(C) Sequential signal voltage.
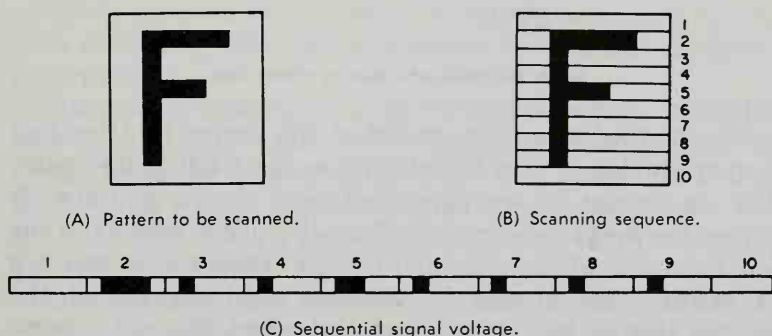
Fig. 3. Development of signal voltages by the scanning process.

If the entire image is repeated at least 16 times a second, the eye will not be able to detect any change. To allow for a safety margin in movies, the scene changes 24 times per

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second; and, as stated previously, for television the rate is 30 times per second. Fig. 4 depicts the projection of a moving-picture film. The transparency is enlarged and focused on a screen by a system of lenses. A rotating shutter is used to present each frame twice, and thereby reduce flicker. The shutter also cuts off the light while one frame is quickly pulled down and the next frame placed in position for projection. Another lamp and lens system focuses a beam of light on the sound track and thence into a photocell. The output from the photocell is an audio signal which is amplified and fed to a speaker.
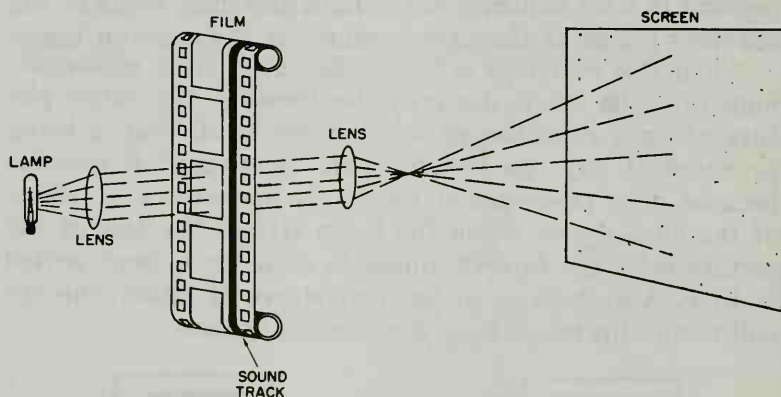
Fig. 4. Projection of a moving picture film.

The method used for scanning the image in television is very similar to that by which you are reading this page. The eye begins at the upper left-hand corner and travels across the first line of words. Then it quickly returns to the left-hand side of the page and travels across the second line of words. This process is repeated until the end of the bottom line of the page is reached when the eye returns to the top of the next page.

In a television system, this scanning is done by the electron beam instead of the eye. The resulting voltage pulses, termed video signals, are then amplified and combined with special artificially manufactured signals for controlling the

timing of the receiver picture-tube deflection circuits and for extinguishing (blanking) the electron beam during the return time. The resulting composite signal is then used to modulate a high-frequency transmitter.

In the standard interlaced scanning system, scanning of the horizontal lines is not performed in sequence. Instead the odd-numbered lines are scanned first, that is, 1, 3, 5, etc., and then the beam returns to the top and scans the even-numbered lines, before the complete scene is scanned. Starting at the upper left extremity of the picture, as in Fig. 5, line No. 1 is scanned. Instead of proceeding then with line No. 2, the scanning beam drops two spaces and No. 2 is omitted. This is because the downward rate has been doubled —60 instead of 30 Hertz (cycles per second). Line No. 3 is then scanned, followed by numbers 5, 7, 9 and every odd-numbered line of the picture. Upon reaching the bottom of the picture, the scanning spot moves again to the top of the picture and begins another scanning field which is displaced from the first by the width of one line so that now lines 2, 4, 6, 8 and all even-numbered lines are scanned.

Since each field is completed in one sixtieth of a second, both fields consume one thirtieth of a second. Thus, 30 complete pictures are scanned in one second, each having been broken up into two projections as a means of flicker reduction.

Given a line frequency of 15,750 and a picture repetition rate of 30 Hertz, the number of lines per picture is 15,750/30 or 525 lines, the number of lines per field being 262½. This is shown in Fig. 5, Notice that *field* 1 ends on a half line and that *field* 2 starts on a half line. Thus, there are 262½ lines for each field.

Approximately 490 of these 525 lines in each frame are active, the remainder occurring during the vertical retrace period (the beam is moving from the bottom to the top of the screen) when the viewing tube is blanked out. It is necessary of course, that complete synchronism be maintained between scanning at the transmitter and at the receiver. To effect this, synchronizing pulses are transmitted

along with the video signal to lock the receiver oscillators, vertical and horizontal, into step with those at the transmitter.

Thus, in addition to the video signal which contains the actual picture signal, four additional signals must be transmitted before the picture can be properly displayed on the screen. The horizontal sync pulse is transmitted to keep
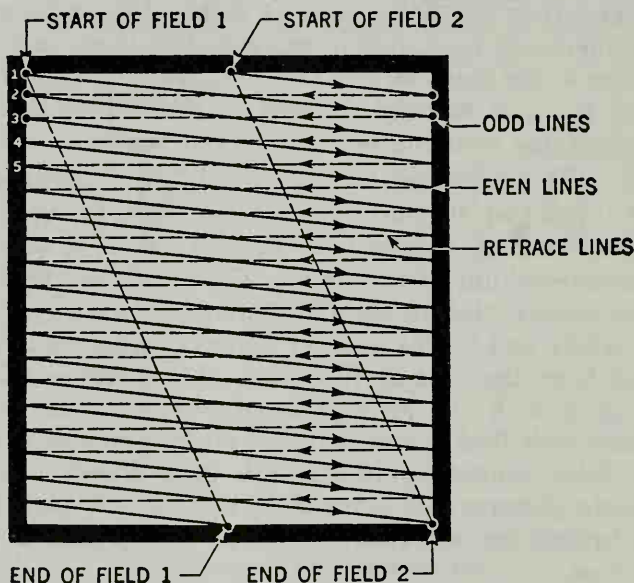
Fig. 5. The interlaced scanning pattern of a raster.

the horizontal deflection circuit in the receiver in step with the left-to-right movement of the scanning beam in the camera. Since the return of the beam from the right to the left of the screen (retrace) would produce objectionable interference if displayed on the screen, a horizontal blanking pulse is transmitted to black out this portion of the scan. Similarly, a vertical sync pulse and a vertical blanking pulse are also transmitted to keep the vertical deflection circuits in step and to blank the beam when it is returning from bottom to top. Chart 2 shows the plan of the sync and sound sections in a TV receiver.

FREQUENCY BANDS

The entire spectrum of radio frequencies is broken down into several portions called bands. These bands, and the designations used to identify them, are as follows:

Band No.	Frequency	Classification	Abbreviation
4	3-30 kHz	Very low frequencies	VLF
5	30-300 kHz	Low frequencies	LF
6	300-3,000 kHz	Medium frequencies	MF
7	3-30 MHz	High frequencies	HF
8	30-300-MHz	Very high frequencies	VHF
9	30-3,000 MHz	Ultra high frequencies	UHF
11	3,000-30,000 MHz	Super high frequencies	SHF
10	30,000-300,000 MHz	Extremely high frequencies	EHF
12	300,000-3,000,000 MHz	Extremely high frequencies	EHF

The assignment of the various types of services (radio, television, radar, amateur, etc.) within the various bands has been partially standardized by international agreements. Thus, world-wide communication is possible, and interference caused by one country operating one type of service and another country an entirely different service on the same frequency is eliminated.

The actual establishment of the operating standards, assignment of portions of the frequency bands listed previously for certain specific purposes, and the assignment of individual frequencies in the United States is controlled by the FCC (Federal Communications Commission).

The standard AM broadcast stations in the U.S. are located between 535 kHz and 1605 kHz, in a portion of the medium frequency band. FM radio broadcasting is assigned the space between 88 and 108 MHz in the VHF band of frequencies.

The frequencies assigned for television broadcasting are located in a portion of the VHF band and a portion of the UHF band. Originally 13 VHF channels, each 6-MHz wide, were allocated for television. Later Channel 1 was deleted. In 1952, 70 additional channels were allocated between

Chart 2. Sync and Sound Section in a TV Receiver
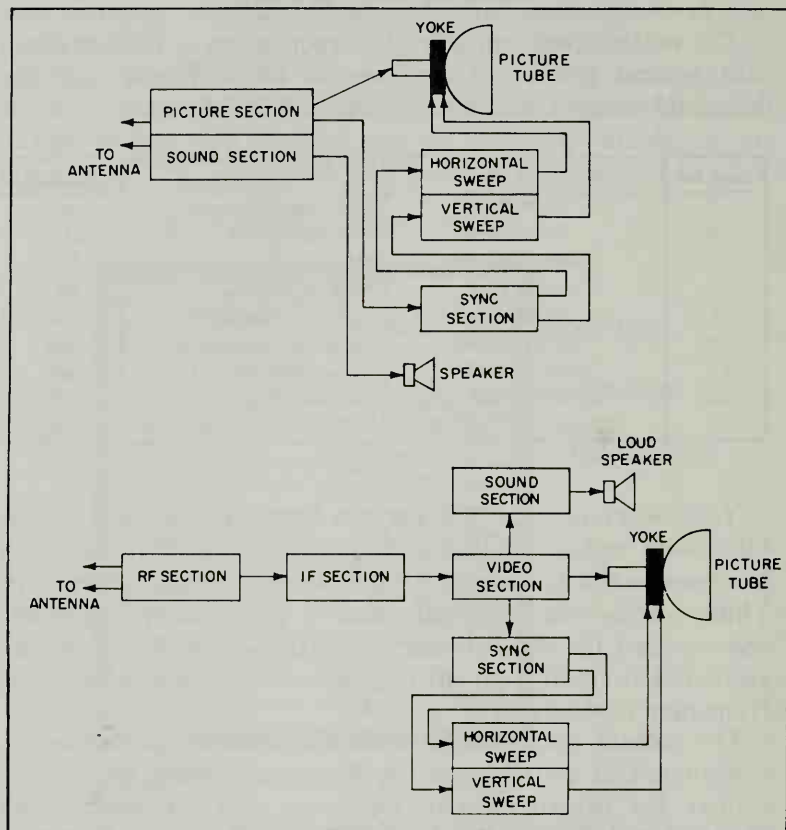
470 and 890 MHz in the UHF band. The frequency assignments for all 82 channels are given in Fig. 6.

The VHF channels are divided in two bands. Channels 2 through 6, called the low-band VHF channels are located between 54 and 88 MHz. There is a 4-MHz break between channels 4 and 5 for other services. Channels 7 through 13, called the high-band VHF channels, are located between 174 and 216 MHz. The frequencies between 88 MHz and 174 MHz are reserved for other services.

From the foregoing it will be observed that a single television channel is 6 MHz wide, in contrast to the entire AM

broadcast band, which is only one MHz wide. Also each AM broadcast channel is only 10 to 20 kHz wide. The reason for the wide television channel is because of the necessity to

Fig. 6. Television channel frequency assignments table:

Channel No.	Picture Carrier Freq. (P)	Sound Carrier Freq. (S)	Freq. Limits
2	55.25	59.75	54 – 60
3	61.25	65.75	60 – 66
4	67.25	71.75	66 – 72
5	77.25	81.75	76 – 82
6	83.25	87.75	82 – 88
7	175.25	179.75	174 – 180
8	181.25	185.75	180 – 186
9	187.25	191.75	186 – 192
10	193.25	197.75	192 – 198
11	199.25	203.75	198 – 204
12	205.25	209.75	204 – 210
13	211.25	215.75	210 – 216
14	471.25	475.75	470 – 476
15	477.25	481.75	476 – 482
16	483.25	487.75	482 – 488
17	489.25	493.75	488 – 494
18	495.25	499.75	494 – 500
19	501.25	505.75	500 – 506
20	507.25	511.75	506 – 512
21	513.25	517.75	512 – 518
22	519.25	523.75	518 – 524
23	525.25	529.75	524 – 530
24	531.25	535.75	530 – 536
25	537.25	541.75	536 – 542
26	543.25	547.75	542 – 548
27	549.25	553.75	548 – 554
28	555.25	559.75	554 – 560
29	561.25	565.75	560 – 566
30	567.25	571.75	566 – 572
31	573.25	577.75	572 – 578
32	579.25	583.75	578 – 584
33	585.25	589.75	584 – 590
34	591.25	595.75	590 – 596
35	597.25	601.75	596 – 602
36	603.25	607.75	602 – 608
37	609.25	613.75	608 – 614
38	615.25	619.75	614 – 620
39	621.25	625.75	620 – 626
40	627.25	631.75	626 – 632
41	633.25	637.75	632 – 638
42	639.25	643.75	638 – 644
43	645.25	649.75	644 – 650
44	651.25	655.75	650 – 656
45	657.25	661.75	656 – 662
46	663.25	667.75	662 – 668
47	669.25	673.75	668 – 674
48	675.25	679.75	674 – 680
49	681.25	685.75	680 – 686
50	687.25	691.75	686 – 692
51	693.25	697.75	692 – 698
52	699.25	703.75	698 – 704
53	705.25	709.75	704 – 710
54	711.25	715.75	710 – 716
55	717.25	721.75	716 – 722
56	723.25	727.75	722 – 728
57	729.25	733.75	728 – 734
58	735.25	739.75	734 – 740
59	741.25	745.75	740 – 746
60	747.25	751.75	746 – 752
61	753.25	757.75	752 – 758
62	759.25	763.75	758 – 764
63	765.25	769.75	764 – 770
64	771.25	775.75	770 – 776
65	777.25	781.75	776 – 782
66	783.25	787.75	782 – 788
67	789.25	793.75	788 – 794
68	795.25	799.75	794 – 800
69	801.25	805.75	800 – 806
70	807.25	811.75	806 – 812
71	813.25	817.75	812 – 818
72	819.25	823.75	818 – 824
73	825.25	829.75	824 – 830
74	831.25	835.75	830 – 836
75	837.25	841.75	836 – 842
76	843.25	847.75	842 – 848
77	849.25	853.75	848 – 854
78	855.25	859.75	854 – 860
79	861.25	865.75	860 – 866
80	867.25	871.75	866 – 872
81	873.25	877.75	872 – 878
82	879.25	883.75	878 – 884
83	885.25	889.75	884 – 890

P = Picture Carrier Freq.   S = Sound Carrier Freq.   All frequencies in MHz

Fig. 6. Television channel frequency assignments.

transmit video information with clarity and sharpness. It also serves to illustrate that video information must be transmitted on very high frequencies to obtain a satisfactory ratio of carrier frequency to bandwidth.

STANDARD TELEVISION CHANNEL

A standard television channel is illustrated in Fig. 7. As previously noted the bandwidth of each television channel is 6 MHz, and both the video and sound signal must be trans-
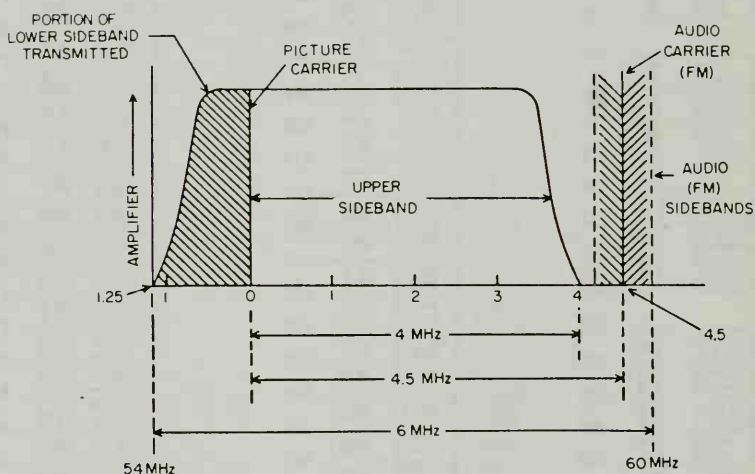
Fig. 7. Signal distribution in a standard television channel.

mitted within this limit. The amplitude-modulated picture signal is always at the low-frequency end of each channel allocation and occupies approximately 5 MHz of the total 6-MHz bandwidth.

The frequency-modulated sound signal is always at the high-frequency end of the 6-MHz channel and has a maximum deviation of 25 kHz (a total carrier swing of 50 kHz). The actual frequencies of the picture and sound carriers are included in Fig. 6.

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An unusual feature of the amplitude-modulated picture signal is that the high-frequency sideband is approximately 4 MHz wide whereas the low-frequency sideband is only 1¼ MHz wide. This unsymmetrical distribution permits transmission of a better definition picture within the 6-MHz bandwidth.

This transmission of one sideband and a portion of the other sideband of the picture signal, as effected in television practice, is termed *vestigial-sideband transmission*.

TELEVISION SIGNAL COMPONENTS

This combination of video, blanking and sync signals is called the *composite video signal*. (See Fig. 8.)

Video-Signal—The video (picture) signal is arbitrarily represented as a jagged line in Fig. 8. (Note, the horizontal
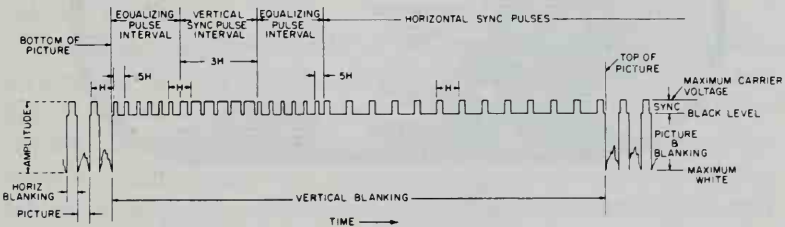
Fig. 8. The composite video signal.

scale of this portion of the signal is greatly compressed in Fig. 8. If drawn to scale, it would be many times wider than the blanking signal.) You will recall that the amplitude of the video signal varies in accordance with the degree of brightness at any particular instant. Fig. 8 shows a typical example. Here, the variations in the tones along line X-X in the picture of Fig. 9A will produce the video modulating voltage of Fig. 9B.

Notice in Fig. 9A that any darker portion of the picture produces an increase in the amplitude of the signal. This type of modulation is called negative polarity of trans-

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mission. Any black area on the screen is represented by an absence of light. In other words, the beam is cut off. This type of transmission is standard in the U.S.

Blanking Signal—Two blanking signals are transmitted —one at the end of each line and the other at the end of each field. Notice in Fig. 8 that the amplitude of the blank-

(A) Television subject.
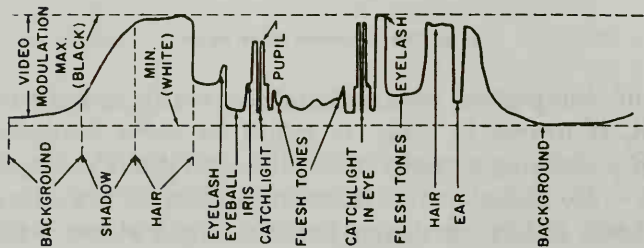
(B) Video voltage.

Variations in the video voltage of a scanning line.

ing signals is greater than any portion of the video signal. Hence, the beam is cut off during the blanking pulses so that

the retrace of the scanning beams cannot be viewed on the screen.

Sync Signal—Sitting atop the horizontal and vertical blanking signals is a rectangular pulse, called the sync pulse. These pulses are employed to keep the deflection circuits in the receiver in step with those at the transmitter. Since the amplitude of the blanking signal is sufficient to cut the beam of the picture tube off, the sync pulse is said to be in the "blacker-than-black" region.

If one long unbroken pulse were transmitted for vertical synchronization, the horizontal sync pulses during this time would be absent. During that time the horizontal deflection circuits in the receivers would lack synchronization and would drop out of step. In order that horizontal synchronization be maintained during the vertical retrace period, the vertical sync pulse is broken by serrations. These serrations then maintain horizontal synchronization during the vertical retrace period.

Equalizing-Pulse—Another or fourth group of signals, termed equalizing pulses, is also included in Fig. 8. These pulses are of shorter duration than the sync pulses and are transmitted to insure uniform spacing of the interlaced scanning lines and to prevent loss of synchronism of the horizontal circuits during the retrace intervals between fields and frames.

In Fig. 8 all pulse shapes, their relative amplitudes, and their duration are standardized. The only variable is the picture signal which varies from line to line as the subject is scanned.

SUMMARY

In summary, the televised picture is broken up into individual elements instead of the entire picture being transmitted simultaneously. A process called interlaced scanning is employed to break up the picture for transmission. In this system, 525 horizontal lines are scanned across the picture.

All odd-numbered lines are scanned first, then the beam returns to the top of the picture and the even-numbered lines are scanned. Thus, two fields of 261½ lines each are interleaved to form the complete picture or frame (525 lines).

The horizontal lines are scanned at a rate of 15,750 per second. Each field of 261½ lines is repeated 60 times per second, and 30 complete pictures consisting of 60 interlaced fields or 525 horizontal lines are transmitted per second. Because the picture tube continues to glow for a period after the beam strikes it and because the persistence of vision of the human eye makes it sensitive only to changes which occur at a rate of 1/16th of a second or slower, we see the complete picture without flicker.

In addition to the picture or video signals, blanking signals to black out the beam during retrace when the beam returns from the right to the left side of the screen and from the bottom to the top of the screen are also transmitted. Sync signals, which keep the receiver deflection circuits in step with the transmitter are situated on top of the blanking signal.

Negative modulation is employed for the picture signal; that is, an increase in the light intensity of the televised scene causes a decrease in the radiated power. Conversely, a decrease in the light intensity causes an increase in the radiated power. The primary reason for adopting negative transmission is that any noise pulse present with the signal will usually cause an increase in the signal strength. With negative transmission, noise will be produced as a black spot, whereas, with positive transmission it would appear as a bright flash of light. The black spots are far less annoying. Also, blanking and sync pulses must be transmitted as black; therefore, with negative transmission, they will appear at the maximum amplitude, assuring proper synchronization even at low signal strength.

The entire composite video signal, including the picture, sync, and blanking signals, plus the sound signal, is trans-mitted in a channel 6-mc wide. To obtain maximum band-

width, a system termed vestigial-sideband transmission is employed. In the United States, 82 channels (12 VHF and 70 UHF) are allocated for television broadcasting.

REVIEW QUESTIONS

1. Radio and television signals are transmitted through space by what means?
2. In radio, how many signals are being transmitted? In television?
3. How many horizontal scanning lines are produced per second?
4. Explain the process used in scanning horizontal lines.
5. How many channels are assigned to television broadcasting?
6. What is the bandwidth of each television channel? Why?
7. How many fields in one complete picture or frame?
8. How many lines in each field?
9. What channels are in the low-band VHF, high-band VHF, and UHF?
10. What range of frequencies is used in the low-band VHF, high-band VHF, and UHF?

Television Transmitters

In this chapter, a brief discussion of the television trans- mitter will be given. This discussion should not be con- sidered as a complete coverage of the subject since that would fill an entire book of this size. Only those points considered necessary for a general understanding of the overall system will be given. A block diagram of the basic TV transmitter system is shown in Fig. 1.

CAMERA TUBES

The camera tube is the heart of the television system. Here the image is first "picked up" and starts its long journey to the receiver picture tube. The basic function of the camera tube is to convert the variable light scenes into a varying electrical signal corresponding to the light and dark areas of the picture.

Two types of camera tubes—image orthicon, and the videocon—will be examined. A brief discussion of the con- struction and operation of each type will be given.

The Image Orthicon—The image orthicon is a storage type of camera tube, having a sensitivity of from 100 to 1,000 times that of the iconoscope. It can deliver an en- tirely satisfactory signal, with negligible noise voltage, from scenes illuminated by very low light levels. Therefore it is suitable for outdoor or studio use.
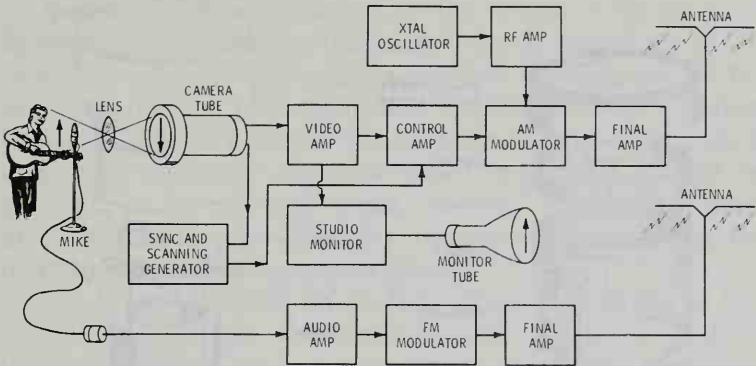
Fig. 1. Plan of the basic TV transmitter system.

The image orthicon achieves its high sensitivity in three ways. They are:

1. By using a conducting photosensitive surface, instead of an insulated mosaic, thereby increasing the photoemission response.

2. By scanning with a low velocity electron beam, thus eliminating the undesirable effects of secondary emission.

3. By using secondary emission in the tube, amplification of the signal is provided.

Structural Details.—This type of television camera tube (Fig. 2) is approximately 15 inches in length, its external diameter being approximately three inches. The fundamental differences from the iconoscope are:

1. The light image is focused on one side of the photocathode, while photoemission takes place from its other side.

2. The scanning takes place on a separate plate called the target, not on the photoemissive surface.

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Fig. 2. A typical image orthicon.

3. The image-modulated current, constituting the video signal, comes from the beam electrons returning from the target toward the cathode from which they came.

Operation.—The operation of the image orthicon is as follows: Light from the televised scene is picked up in the conventional way by an optical system and focused on the semitransparent photocathode. The photocathode emits electrons in proportion to the amount of light falling on it and these electrons are accelerated toward the target by grid No. 6. An external focus assembly focuses the beam of electrons. Further focusing is achieved by varying the potential applied to the photocathode.

The target consists of a thin glass disc with a fine mesh screen on the photocathode side. Electrons striking the photocathode cause secondary emission from the glass. However, the wire mesh, which is maintained at a constant potential of approximately 1 volt, collects these secondary emission electrons. This action limits the potential of the glass disc and makes it very stable for different light intensities. The electrons emitted from the photocathode side of the target cause a positive charge, which varies according to the intensity of the scene being televised, to be built up on the other side of the glass disc. The foregoing actions const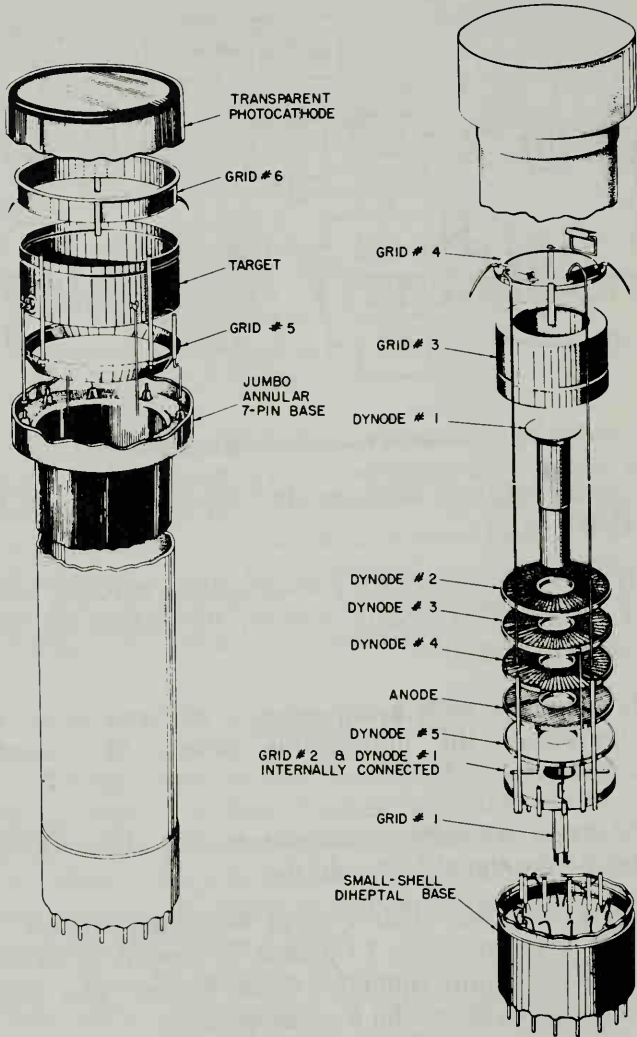itute the image section of the image orthicon. These actions are independent of the electron beam and scanning circuits of the tube.

The back side of the target is scanned by a low-intensity electron beam. This beam is focused by an external magnetic field and the electrostatic field created by grid No. 4. Grid No. 5 serves to decelerate the field before it strikes the target. When the beam strikes the target, it is turned back and focused on dynode No. 1. However, some of the beam electrons are used to neutralize the charge on the glass of the target, the amount depending upon the charge at the particular area being scanned. If a more positive area, corresponding to a brighter area is being scanned, more beam electrons will be needed to neutralize the target and fewer electrons will be returned to dynode No. 1. Hence, the intensity of the beam returned to dynode No. 1 depends on the intensity of the image being scanned.

When the electrons strike dynode No. 1, several electrons are emitted for each one which strikes the dynode. These

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secondary electrons from dynode No. 1 strike dynode 2 where the process is repeated—for each electron which strikes the dynode several are emitted toward the next dynode. The action is continued for dynodes 3, 4 and 5 until the electrons strike the anode which is the final element in the multiplier chain. The output of the image orthicon is taken from across a load resistor connected between the anode and the power supply.

The total multiplication obtained by the multiplier section is approximately 500. When a brighter area is being scanned, less current flows, giving a positive output. Thus, the output of the image orthicon is positive; that is, when the brightness increases, the signal also increases in a positive direction.

Vidicon—The vidicon (Fig. 3) is suitable for black-and-white or color television and is used in both broadcasting and closed-circuit applications. The tube consists of an electron gun, beam-focusing electrode (grid 3), fine mesh screen (grid 4) and a target.
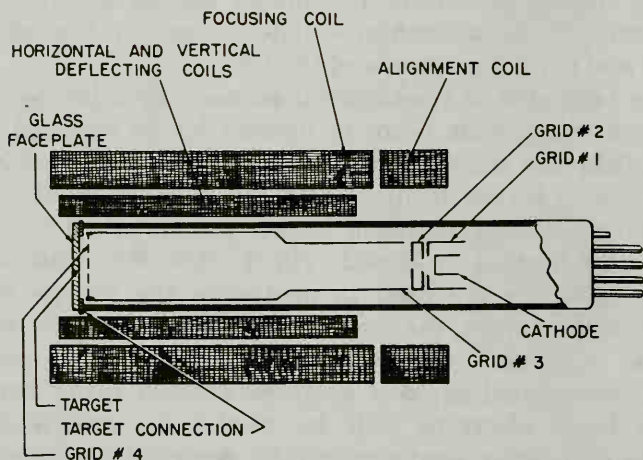

Fig. 3. Structural arrangement of a vidicon.

The electron gun consists of a cathode, control grid (grid 1), and an accelerating grid (grid 2). A low-velocity

beam from the electron gun is focused by an external
magnetic field and by the electrostatic field of grid 3. Grid
4, which is connected to grid 3, is positioned near the
target. The target is composed of a transparent conducting
film on the inner surface of the faceplate. Each small
portion of the photoconductive layer is an insulator
when there is no light on the faceplate, but becomes slightly
conductive when illuminated.

Grid 4 provides a uniform decelerating field between it-
self and the photoconductive layer of the target so the
beam approaches the layer perpendicular to it. This con-
dition is necessary for linear scanning. The beam is de-
flected back and forth and up and down on the target.
Since the photoconductive layer has a positive potential,
electrons are deposited on it when it is scanned by the
beam. This depositing of electrons continues until the
surface potential of the photoelectric layer is reduced to
that of the cathode. When this point is reached, electrons
are turned back to form a return beam that is not used.
Deposits on the scanned surface of any portion of the
layer change the difference of potential between the two
surfaces of the portion. When the two surfaces of the por-
tion, which in effect is a charged capacitor, are connected
through the external target circuit and the scanning beam,
a capacitive current is produced. This current is the video
signal.

Monoscope—The monoscope is used in the development
of television signals used for testing and adjusting studio
equipment. The main difference between the monoscope
and the other types of camera tubes is that it has a test
pattern in the front of the tube envelope. This test pattern
is reproduced as the video signal.

The output signal is produced by the difference in sec-
ondary emission of two materials. For example, a high-
carbon ink, which has a low emission, can be used to
print the pattern on a sheet of aluminum which has a high
emission. As the beam scans the entire surface, secondary
emission electrons are emitted from both materials in pro-
portion to their emission ratios.

SYNC GENERATOR

As previously explained synchronizing pulses, generated at the transmitter, control the deflection of the electron beams in the camera tube and in the receiver picture tube. The sync generator in the transmitter produces the properly timed and shaped pulses for the horizontal and vertical deflection of the beam in the camera. In addition, these pulses are added to the video signal to keep the receiver in step.

BLANKING GENERATOR

The proper pulses for cutting off the camera and the receiver during the retrace period are generated in the

Courtesy Ampex Corp.

Fig. 4. A typical TV monitor.

blanking generator. These pulses are also added to the video signal before transmission to the receiver.

VESTIGIAL-SIDEBAND FILTER

As discussed previously, only a portion of the lower sideband is transmitted. A portion of the lower sideband is removed to conserve space in the spectrum. This portion of the signal is removed by the vestigial-sideband filter.

SOUND TRANSMITTER

The sound transmitter associated with the transmitting system is a conventional frequency-modulation system consisting of audio amplifier, frequency modulator, high-
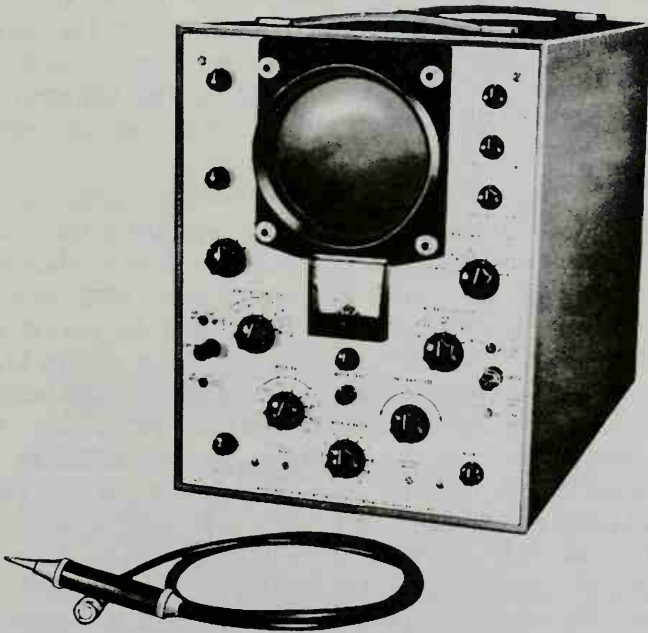
Courtesy Simpson Electric Co.

Fig. 5. A TV oscilloscope.

frequency transmitter and high-frequency antenna. Thus, at the transmitting station, there are actually two transmitters—one for the picture signal, and one for the sound.

Television Broadcasting Practices—In the foregoing overall description of a television system no attention has been given to the apparatus necessary in the broadcasting studios for a successful transmission of picture and sound. Most of the apparatus required to produce the conditions described are of necessity extremely complex and an understanding of them is unnecessary. However, a *monitor* is comparatively simple, and is of interest in this basic analysis. A typical monitor is illustrated in Fig. 4. It is a simplified type of TV receiver, which contains scanning circuits, a video amplifier, and a picture tube. The monitor is used at the TV broadcast station to permit the station engineer to observe the system operation. If the engineer did not have a monitor, he would be "working in the dark." A monitor is supplemented by an oscilloscope, such as illustrated in Fig. 5. The scope enables the engineer to determine whenever distortion might occur in the video signal.

The televising of live talent programs presents to the video broadcaster many of the same problems that have confronted the moving-picture industry. Rather elaborate backgrounds are frequently necessary and they require the same attention to technical detail and to period authenticity that is evident in well staged plays and in high-grade motion pictures. However, unlike the motion-picture production which can be interrupted at will, a live television broadcast must be continuous. The problems of set lighting and equipment placement require much planning and rehearsal prior to the actual broadcast.

Indoor, as well as outdoor televising usually requires that several cameras be strategically located so that the scene can be viewed from various vantage points without sequential interruption.

In addition to the telecasting of live program material, extensive use is made of motion-picture film in television

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programming. For this purpose, special projectors are employed, which by a shutter arrangement, convert the 24-frames-per-second film projections into 30-frames-per-second television signals. The film picture is projected directly into the television camera tube, from which the electrical signal is conveyed to the control room over coaxial cable. Sound pickup from the film is in the normal manner.

Courtesy Ampex Corp.

Fig. 6. A typical video tape recorder.

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In addition to regular movie film, other films are often used. For instance, film is often used for news and commercials. The sound may or may not be included on this film. When the sound is not included, the sound may be provided by a live announcer, an audio tape, or a record.

Slides may also be used for still commercials. Here again, the sound will be provided by an announcer, tape, or record.

Video tape recorders are used for many programs. They offer the advantage of being able to record the program at any convenient time for playback at the desired time. Both the picture and sound are included on the magnetic tape and it is ready for instant playback. No time is lost in processing. Video tapes can be exchanged between stations or distributed by syndicates the same as film. They can also be used for commercials or any other type of presentation.

Network broadcasts, of course, are one of the most common methods of program origination and do not require any program facilities at the local studio. In this type of presentation, the program originates at one point—either live, on film, or on video tape. This program is then sent out via coaxial cable and/or microwave relay to the stations of the network. At the stations, it is transmitted to the viewing public. Sometimes, due to time differentials, the network
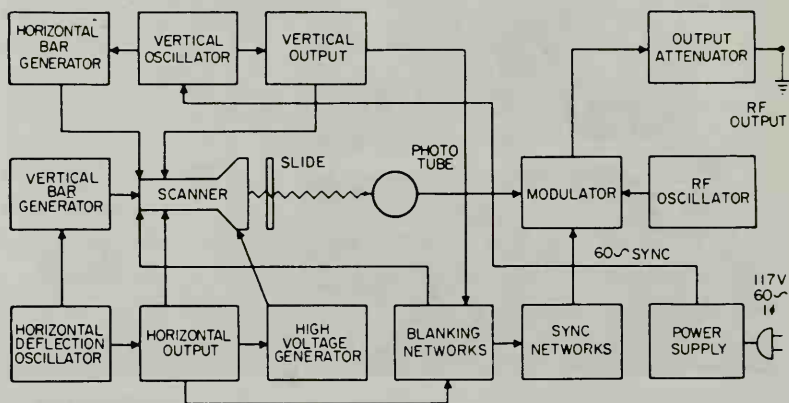
Fig. 7. Block diagram of a flying-spot scanner.

program will be recorded on video tape when it is received at the station and played back at a later hour. Fig. 6 illustrates a typical video tape recorder.

Remote broadcasts offer still other difficulties. Since the connection, by coaxial cable, from a remote place to the studio control room equipment is an economic impossibility, small ultra-high frequency radio relay links are employed to relay remote pickups.

The relay equipment is usually contained within a special truck which houses not only the relay transmitter but also complete control and monitoring facilities. Of course, if the event is not to be viewed until a later hour, the program can be filmed or taped at the remote location. The film or tape facilities can be taken to the remote point and transported back to the studio, or the radio relay can be utilized and the recording made at the studio.

A flying-spot scanner used in television troubleshooting procedures is a miniature TV transmitter that converts a transparency into a video signal. Fig. 7 shows a block diagram for a flying-spot scanner. A cathode-ray tube is used as the source of the flying-spot light beam. As the transparency is scanned, a phototube develops the video signal, as depicted in Fig. 8.
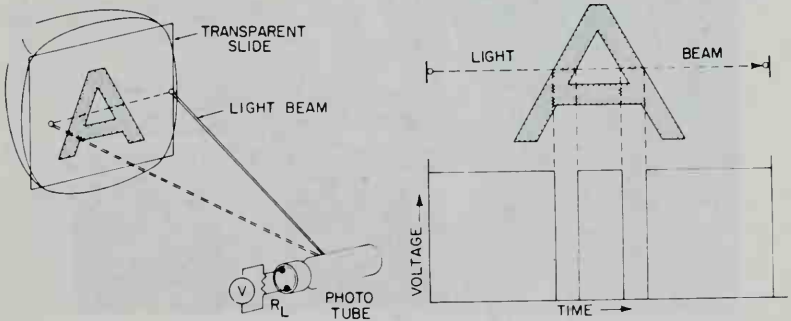
Fig. 8. Phototube converts light to a signal voltage.

Closed-circuit television originally designated a local system consisting of a TV camera and several monitor

receivers connected by coaxial cables. Today, closed-circuit TV refers also to elaborate private installations, which are in wide use by industry, commerce, and education. Microwave transmission are used in some of the larger "closed-circuit" TV systems. The basic distinction is in the fact that only private groups are served by a closed-circuit system. Scanning standards are usually the same as used in public
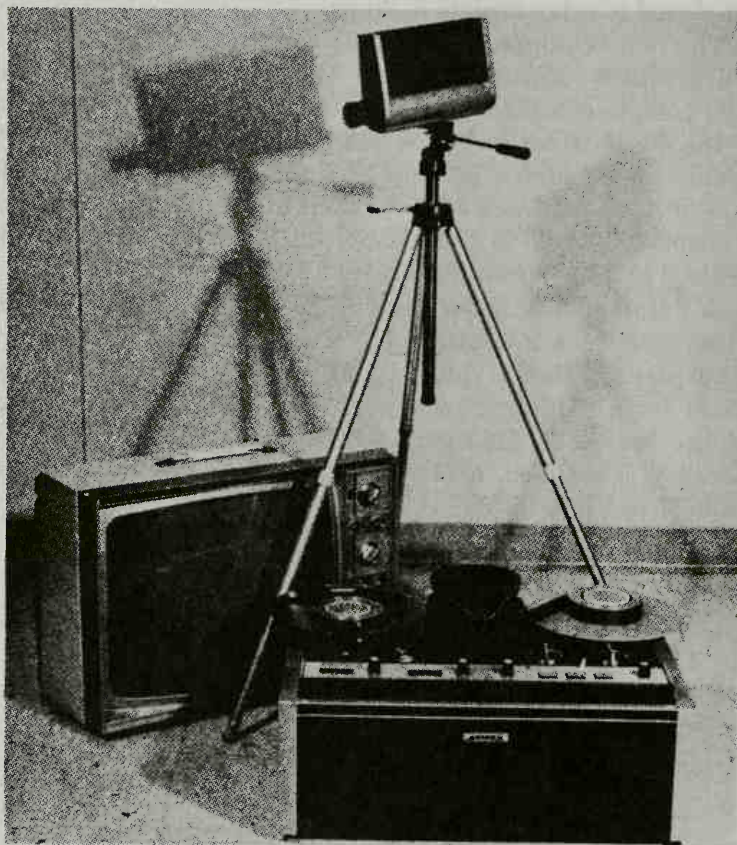
Courtesy Ampex Corp.

Fig. 9. A closed-circuit TV camera, monitor, and a video-tape recorder.

TV broadcasting, although slow-scan standards for example, may be used to transmit signature records in banks.

TELEVISION TRANSMITTERS

Equipment used in closed-circuit TV is similar to conventional broadcast-TV equipment, except that the units may be less elaborate. For example, the TV camera illustrated in Fig. 9 employs a *vidicon tube*. An RF signal output is provided, which is usually fed to conventional TV receivers via coaxial cables. Video tape recorders, such as seen in Fig. 9, find wide use in educational installations. It provides a video-frequency signal, which is fed via a coaxial cable to the TV receivers, and applied directly to the video amplifier in each receiver. The TV camera may be used when "live" classroom activities are to be transmitted by the closed-circuit system.

Since a typical closed-circuit TV camera produces a video signal with a bandwidth up to 10 MHz, the chief limitation on picture detail and quality is imposed by the TV receivers used in the viewing locations. Most cameras provide video-frequency output in addition to RF output. If the video-signal output is applied directly to the video amplifier in a receiver, the quality of picture reproduction may exceed that of a standard TV broadcast program. Practically all closed-circuit cameras are transistorized, compact, and can be operated by anyone who understands how to focus an ordinary camera. Closed-circuit color TV is used chiefly in medical schools.
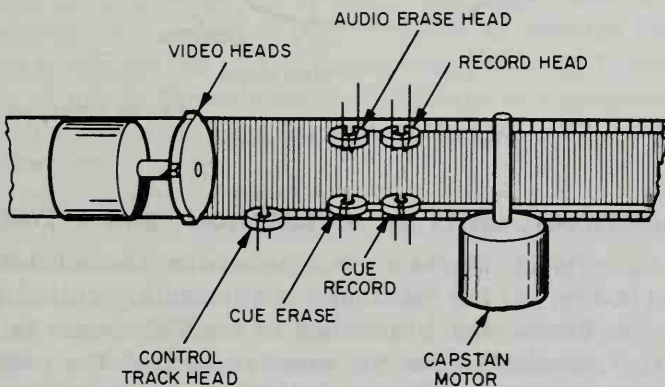
Courtesy Ampex Corp.

Fig. 10. Transverse recording method.

A video tape recorder employs magnetic tape to record moving pictures and sound. A typical method utilizes transverse recording with a rotary head (see Fig. 10). The video tape is two inches wide, and moves past recording heads at 15 or 7½ inches per second. However, four record/playback heads are mounted on a disk that rotates rapidly across the tape at virtually a 90 degree angle to the path of the tape. The relative tape-to-head speed is increased to 1500 inches per second. Frequencies up to 5 MHz can be recorded. In helical recording (see Fig. 11), one or two record/playback heads are mounted on a moving drum and move across the tape in a diagonal curve. The tape may be from one-half to two inches wide, and the tape speed may be from 3.75 to 9.6 inches per second. Frequencies up to 3.2 MHz can be recorded by this method.
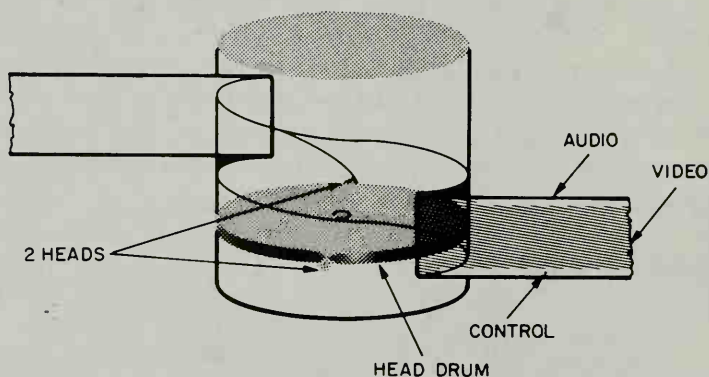
Courtesy Ampex Corp.

Fig. 11. Helical recording method.

FUNCTIONAL UNITS OF A TELEVISION TRANSMITTER

A basic block diagram of a television transmitter is shown in Fig. 12. The viewfinder is an auxiliary optical and electronic device that is attached to the TV camera to enable the operator to see the same scene that the camera is transducing. A stabilizing amplifier functions to correct faulty video signals from field pickup equipment and trans-
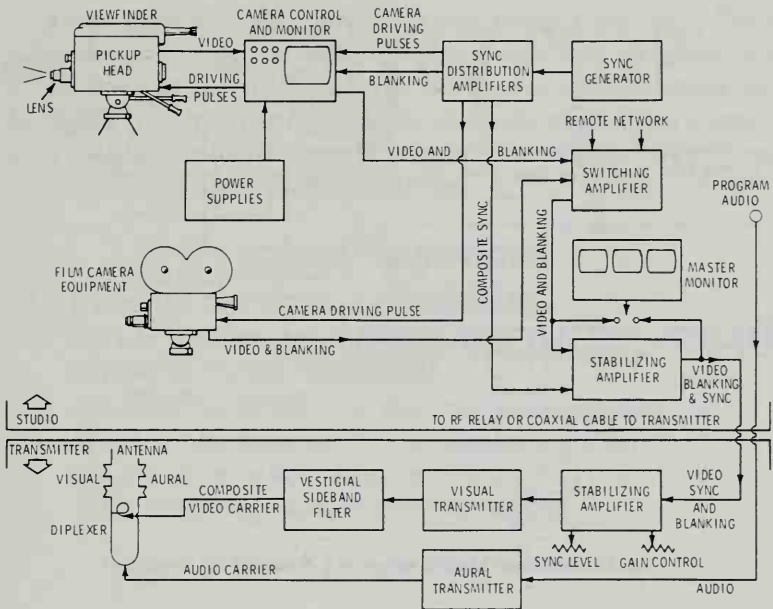
Fig. 12. Block diagram of a television transmitter.

mission characteristics such as noise, switching surges, improper sync-to-signal ratio, and so on. The stabilizing amplifier includes circuits for separating sync signals, wave-shapers, sync insertion circuits, and video amplifiers. A vestigial sideband filter is a filter that is inserted between an AM transmitter and its transmitting antenna to suppress part of one of the sidebands. A diplexer is a coupling unit which allows more than one transmitter to operate together on the same antenna.

Next, observe the functional block diagram of a channel-6 TV transmitter, shown in Fig. 13. Operating frequencies and the chief frequency responses are noted in the diagram. Note that grid modulation is utilized for the picture signal. This form of modulation preserves the dc component of the video signal without undue circuit elaboration. In the studio chain, the dc component of the video signal is reinserted by means of a clamper (dc restorer). Unless the dc com-

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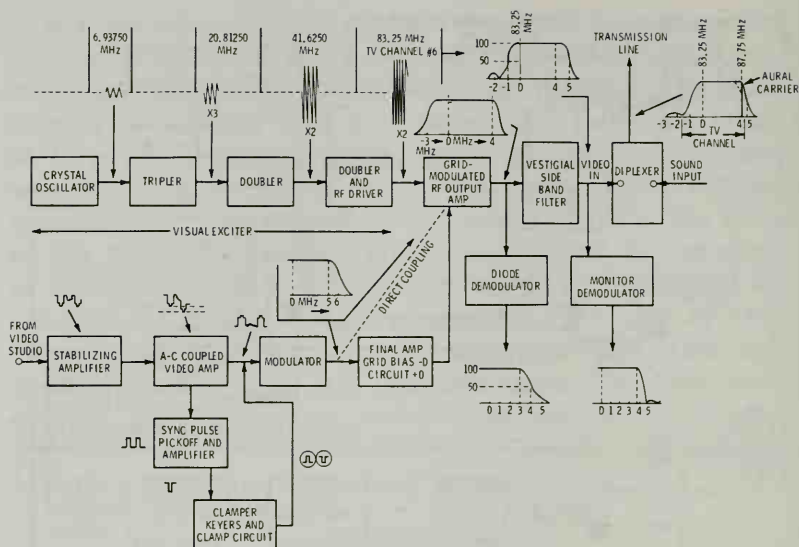
Fig. 13. Functional block diagram of a channel-6 TV transmitter.

ponent is maintained, night scenes will appear too light, and day scenes will appear too dark. As explained subsequently, TV receivers may or may not be designed to preserve the dc component of the video signal.

SUMMARY

There are basically two types of TV camera tubes; the image orthicon and the vidicon. The basic function of the camera tube is to convert the variable light scenes into a varying electrical signal corresponding to the light and dark areas of the picture.

Sync generators, blanking generators, vestigial-sideband filters, and audio transmitters are all part of the signal transmitted for properly shaped pulses for horizontal and vertical deflection, proper blanking during retrace, and proper sound at the television receiver.

Video tape recorders are used for many programs. They offer the advantage of being able to record any program for a playback at the desired time. Both sound and picture are included on the magnetic tape and are ready for instant playback because no time is lost in processing. Video tape is often used for commercials.

REVIEW QUESTIONS

1. Name the two types of camera tubes.
2. Why is the monoscope camera tube used for testing and adjusting studio equipment?
3. What is the purpose of the sync pulse transmission?
4. What is the purpose of the blanking pulse?
5. Why is a monitor used in transmitting studios?
6. Why are video tape recorders used?

CHAPTER 3

Television Receivers

In the previous chapter, a discussion of the various stages in a television transmitter was given. In this chapter, the same type of presentation will be given for the television receiver. The function of the television receiver is to pick up the signal from the television station, amplify it, and employ it to produce visible pictures and audible sound which, in all details, correspond to the original scene. (See Fig. 1).

In the television receiver, the received signal is amplified and separated into its individual components. These components are amplified and applied in such a way as to produce variations in the intensity of the electron beam of the picture tube. Fig. 2 depicts the components of the received signal.

Deflection of the beam in the picture tube is accomplished electromagnetically with coils external to the tube. The oscillators which supply the energy to deflect the beam in the picture tube operate at the same frequency as the deflection circuits associated with the camera tube at the picture tube. The deflection circuits in the receiver are kept in step with the deflection circuits in the camera by the sync pulses transmitted as part of the composite video signal.

Thus, the electron beam of the picture tube moves in synchronism with the electron beam of the camera tube, and the variations in brilliance at the point of impact on the picture-tube screen correspond to the illumination on the

respective areas of the camera tube. In this manner, the image on the target of the camera tube is dissected and
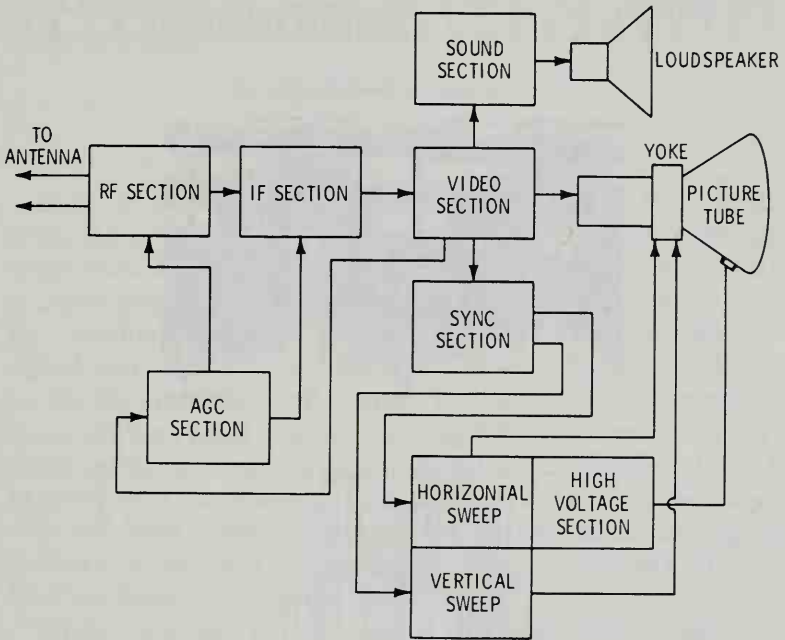
Fig. 1. Fundamental block diagram of a television receiver.

the information on each element is transmitted separately in a manner that permits the television receiver to take the pulses of information and employ them to produce variations in illumination on the picture-tube screen. Since the deflection circuits keep these pulses of illumination in the same respective positions on the screen, a reproduction of the original scene is produced.

BLOCK DIAGRAM OF TELEVISION RECEIVER

It should be understood that all television receivers operate on the same general principles. All use the superheterodyne principle. All must have certain basic stages. The actual circuits may differ, but their function is the same.

(A) Sync pulses and blanking pedestals.
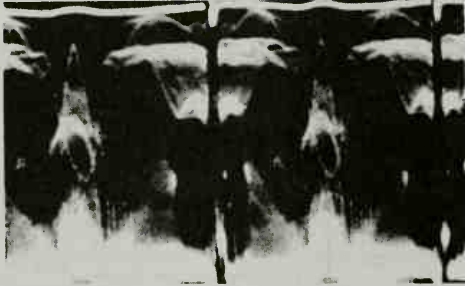
(B) Camera signal.
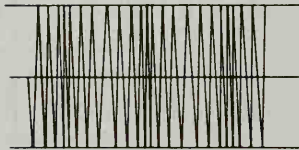
(C) Sound signal.

Fig. 2. Basic components of the television signal.

In order to simplify the study of television receiver, it is customary to employ *block diagrams*. When you first look at the circuit of a complete TV receiver, it looks frightening and very complicated. However, by using the block diagram, the complete circuit can be broken down into its individual sections, each of which has its own function.

The block diagram of a television receiver is given in Fig. 3. The block diagrams of some will be different, but all will be basically the same. All of the stages or blocks shown in Fig. 3 are not used in some receivers, depending on their

intended price range and application. The blocks shown in dashed lines in Fig. 3 are the ones most commonly omitted. Typical stage-gain figures for a television receiver are noted in Fig. 4.

THE TUNER

Here is how a typical TV receiver works: The signal from the desired VHF TV station and the signals from all other stations in the area arrive at the VHF antenna. All of these signals travel down the transmission line to the RF amplifier. The RF amplifier selects only the desired signal and rejects all others. The desired signal is amplified by the RF amplifier and coupled to the mixer. In the mixer stage the amplified signal from the RF amplifier and a signal from the local oscillator are beat together (heterodyned) to produce a lower, or intermediate frequency. The mixer and the local oscillator are shown in one block in Fig. 3 because, in modern TV receivers, these stages are always two portions of the same tube.

When receiving a UHF signal, the procedure is slightly different from that described in the foregoing. The signals from the UHF station also arrive at the antenna. The UHF signals travel down the transmission line and arrive at the UHF tuner, where the signals from the desired station are selected and applied directly to the mixer stage. Here the signal from the station and the signal from the UHF local oscillator are heterodyned to form the IF frequency. The IF output from the UHF tuner is then coupled to the VHF RF amplifier. When tuned to the UHF position, the VHF RF amplifier and mixer provide two stages of amplification of the IF signal. Note that actually two separate IF signals exist at the mixer output. One is produced by the video signal beating with the local oscillator. A typical video IF frequency is 45.75 MHz. The other IF frequency is produced by the sound signal beating with the local oscillator. A typical sound IF frequency is 41.25 MHz. Thus, the two
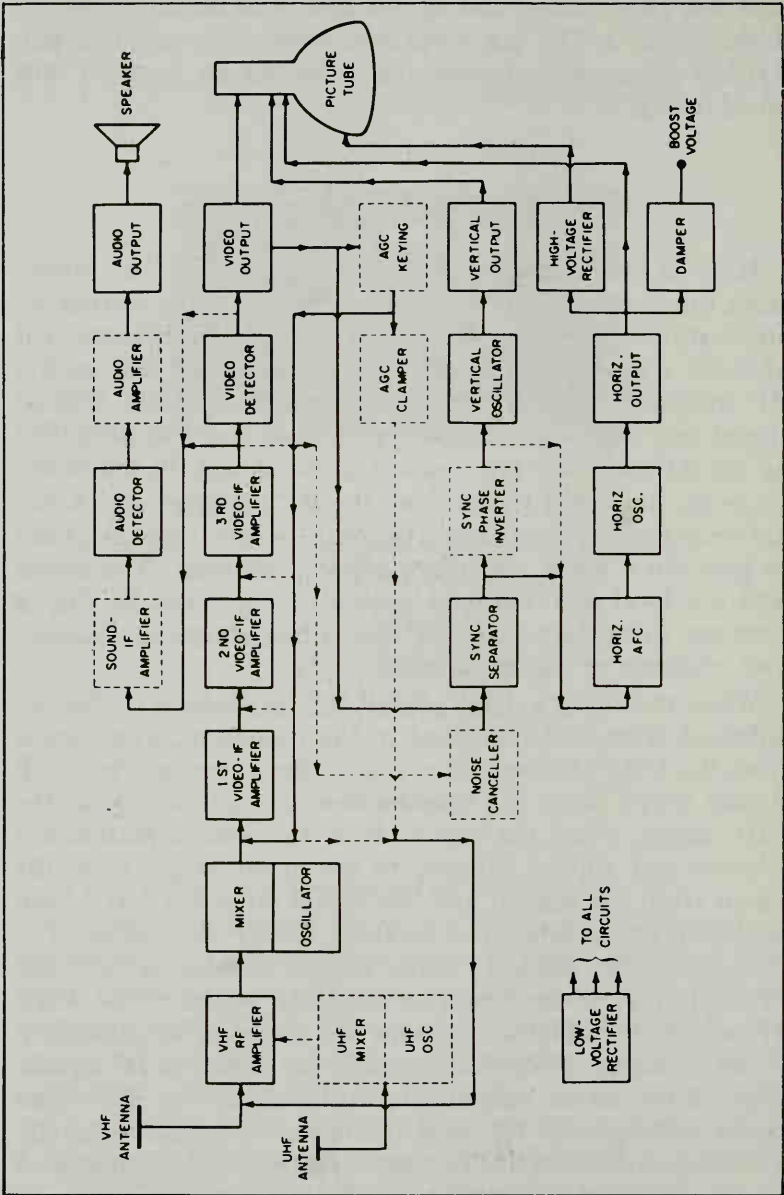
Fig. 3. Block diagram of a television receiver.

frequencies are separated by the same 4.5-MHz difference
established at the transmitter.

For example, assume that it is desired to tune to a station
operating on Channel 6, whose video carrier frequency is
83.25 MHz and sound carrier is 87.75 MHz. The local oscilla-
tor frequency in this example would be 129 MHz. Thus, when
the local oscillator is heterodyned with the station signals,
the following IF frequencies are generated:

Local Oscillator ....129.00 MHz
Minus Video Carrier .... 83.25 MHz
                                        ————
Video IF .... 45.75 MHz
Local Oscillator ....129.00 MHz
Minus Sound Carrier .... 87.75 MHz
                                        ————
Sound IF .... 41.25 MHz
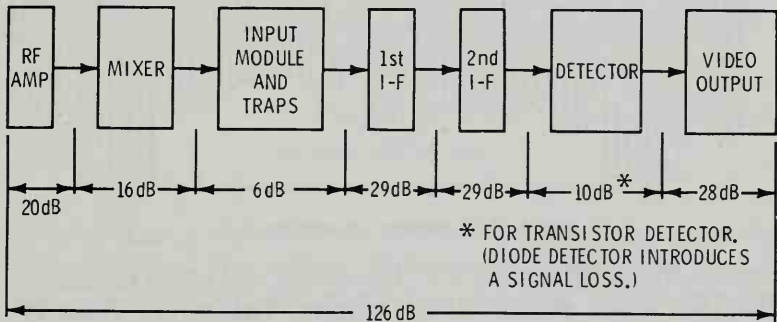
Fig. 4. Typical gain figures for a television receiver.

Notice, that although the sound carrier in the composite
video signal is transmitted at the higher frequency, the
lower IF is produced by the sound carrier because the
oscillator is at a higher frequency than either carrier, and
there is an inversion of the frequency relationship between
the sound and picture carriers. If the local oscillator were
tuned to a frequency lower than the carrier frequencies,

the video IF would be lower than the sound IF. Either method will work; however, the former is usually employed because of interference problems when the oscillator is tuned lower than the carrier.

VIDEO-IF AMPLIFIER, DETECTOR AND VIDEO AMPLIFIER

The output of the mixer is coupled to the input of the first video IF amplifier. Remember, the signal at this point contains both video and sound, as well as the sync signals, although the stages are called video- (or picture) IF ampli-
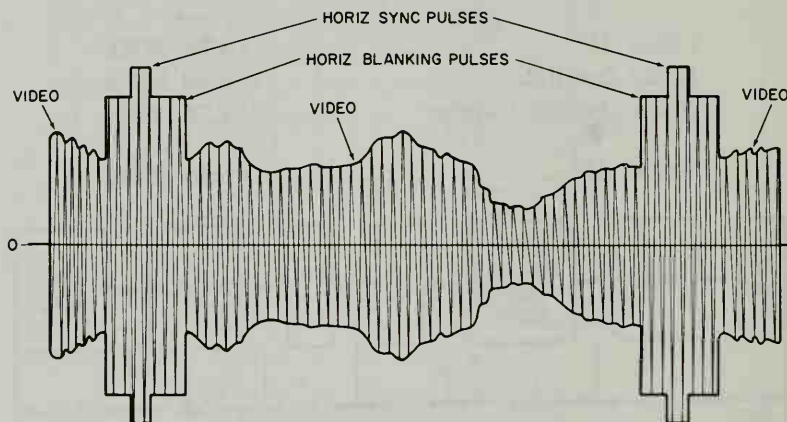
Fig. 5. The composite video-IF signal.

fiers. In the early days of TV, the sound was often separated from the video at the mixer output. The term "video-IF amplifier" is a carry-over from the days when only the video (and sync) signal was applied to these stages but in all modern receivers, both video and sound are being amplified by these stages.

The IF amplifiers are tuned to pass a band of frequencies approximately 4 MHz wide and to reject all others. This wide-band response is obtained by using various means of coupling between the IF amplifier stages. Thus, the signal in the video-IF amplifiers is an RF signal, varying at the video rate, as shown in Fig. 5. Three stages of video IF

amplification are shown in Fig. 3 ; however, some receivers may have four and others only two. In fact, TV receivers have been manufactured with only one video-IF amplifier.

At the output of the last video-IF amplifier, the signal is coupled to the video detector. The video detector detects, or demodulates, the video-IF signal so that a DC voltage,

(A) Positive-going sync.

(B) Negative-going sync.
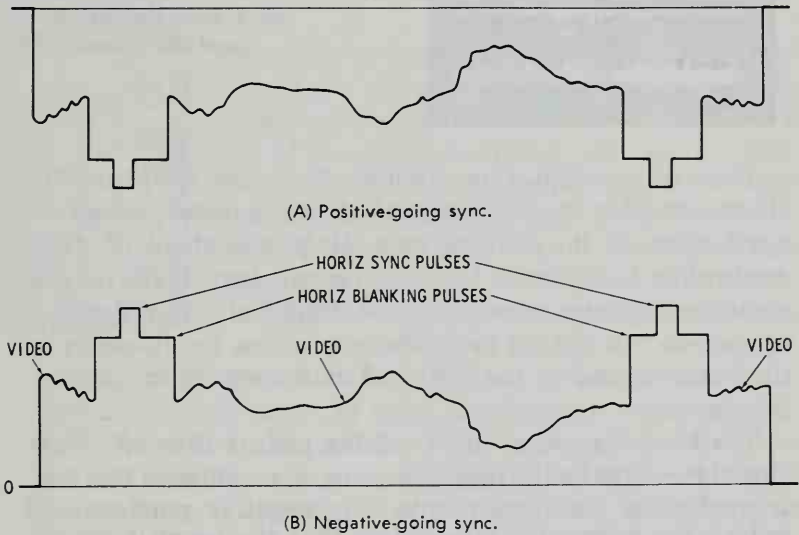
Fig. 6. The composite video signal after detection.

which varies in step with the original video and sync signals, is produced at the output. This signal is shown in Fig. 6. Fig. 7 shows how the composite video-IF signal appears on the scope screen, after detection.

In addition to the signal of Fig. 6, another signal is produced at the output of the video detector. Recall that, in addition to the video signal, the sound signal is also present in the video-IF amplifiers, and that the carrier frequencies for these two signals are separated by 4.5 MHz. These two signals beat together in the video detector, producing a new signal, whose frequency is equal to the 4.5-MHz difference between the signals. This new signal contains all the sound information, so it is a new sound-IF frequency. Because

the signal was produced by the beating together of the two signals, it is called the *intercarrier* sound signal and is always 4.5 MHz. Fig. 9 shows how a 4.5 MHz signal appears as "fuzz" on the video signal.

Fig. 7. Scope display of video signal after detection.

The video output stage follows the video detector. This stage amplifies the weak signal at the detector output for application to the picture tube. Only one stage of video application is shown in Fig. 3; however, two stages may be employed in some receivers. The amplified video signal is applied to the picture tube where it varies the intensity of the beam to produce the light and dark spots on the picture-tube screen.
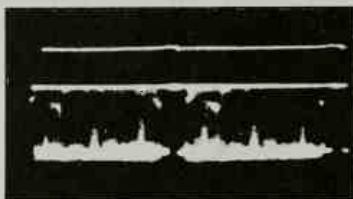
The blanking pulses must cut the picture-tube off. Thus, if a video signal with negative-going sync pulses (Fig. 8A) is applied to the picture tube, the negative portions will reduce the voltage at the grid so that the beam is cut off. When the more positive portions of the signal are applied to the grid, the beam will flow from the cathode to the screen in the picture tube. The intensity of the beam at any instant and, hence, the degree of brightness of the spot on the screen will depend upon the instantaneous voltage of the signal—the more positive the signal, the more intense the beam and the brighter the spot on the screen.

If a positive-going sync signal (Fig. 8B) is applied to the picture tube, the results will still be the same, except the signal must be applied to the *cathode* of the picture tube. As the positive-going sync pulses are applied to the picture tube, the instantaneous voltage at the cathode is made more positive which, if the grid voltage remains constant, is the same as making the grid more negative. In

either case, the difference in potential between the two elements is increased, and it is the difference in potential —not the actual voltage—that controls the amount of con- duction of the tube. During the negative portions of the signal, the potential on the cathode approaches that of the grid; thus, the tube is allowed to conduct—the amount depending upon the actual voltage difference between the two elements.

In modern television receivers, the signal may be applied to either the grid or the cathode. Either polarity is easily obtained. Recall that each time a signal is amplified by a stage, the polarity of the signal is shifted 180°, or reversed. Either a positive or a negative-going signal can be obtained from the video detector stage, depending upon which ele- ment the output is taken from. Thus, if the signal has negative-going sync at the detector output, and is amplified by a single video amplifier stage, positive-going sync pulses will be applied to the picture tube. This is the correct po- larity for application to the cathode of the picture tube. However, if two stages of video amplification are employed, the signal will again be shifted 180° making the sync-pulse polarity negative—the correct polarity for applying to the grid of the picture tube. If a positive-going sync signal is obtained from the video detector, the situation is reversed. With a single video amplifier stage, the signal is correct for applying to the grid of the picture tube; with two stages of video amplification, the proper signal for application to the cathode of the picture tube is obtained.

SOUND SECTION

Recall that at the output of the video detector, a 4.5-MHz signal which was frequency modulated with the audio (sound) signal was produced. Sometimes, the sound signal is removed directly following the video detector and some- times, it is further amplified by the video amplifier before removal. Four methods of sound and sync signal take-off are shown in Fig. 10.
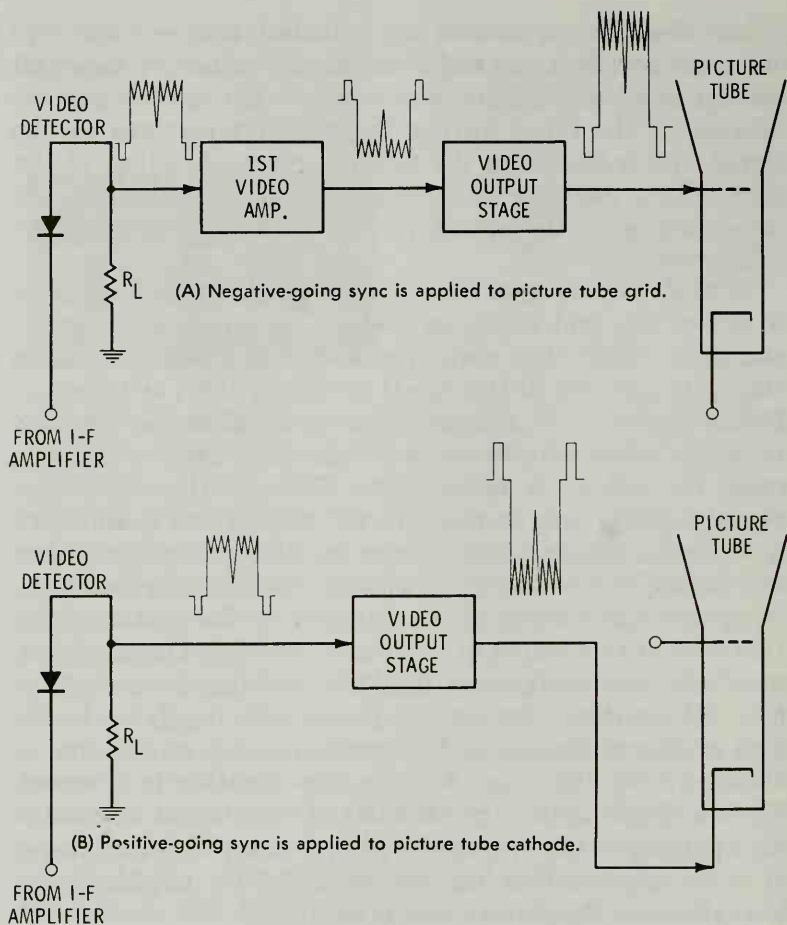
Fig. 8. Video signal polarity versus picture tube drive.

As indicated by the dashed-line box in Fig. 3, the sound-IF amplifier may or may not be included in the circuit. In addition, some receivers may employ two stages of sound-IF amplification. From this point on, the sound section is very similar to that of an FM radio. The sound signal is detected by the audio detector and the audio signal, which corresponds to the original sounds at the transmitter, appears. This signal is amplified by the audio amplifier and
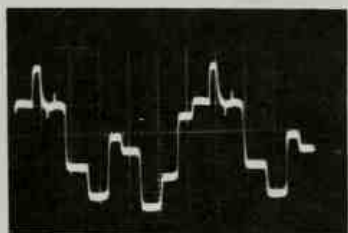
(A) Moderate level of intercarrier signal.   (B) High level of intercarrier signal.
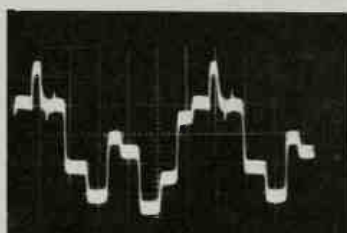
Fig. 9. Video signals with a 4.5 MHz intercarrier sound signal.

audio output stages and applied to the speaker where the electrical signal is converted to audible sound. Notice, in Fig. 3 that the audio amplifier is sometimes omitted. When this stage is omitted, audio amplification is provided by the audio detector in addition to the detector action.

The sound system described in the foregoing is called the *intercarrier* system. In this system the sound IF is always 4.5 MHz—the difference between the sound and the video carriers. This system is employed in all present-day television receivers. In earlier receivers, the sound-IF signal was removed at the mixer output or at some point in the video-IF amplifiers. In this system, called *dual channel* or *split* sound, the sound IF will be 4.5 MHz removed from the video-IF (usually in the 20-MHz region in these early receivers). In systems employing this type of sound circuits, two or more sound-IF amplifier stages are used. Otherwise, the frequency of the IF is the only difference between the dual-channel and the intercarrier systems.

AGC CIRCUIT

Just as an AVC circuit is employed in radios to compensate for changes in the strength of the received signal, some means must be included in TV receivers to compensate for changes in signal strength. In Fig. 3, a portion of the signal from the video output tube is coupled to the

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(A) Both following video output.

(B) Both preceding video output.

(C) Sound take-off preceding and sync take-off following video output.

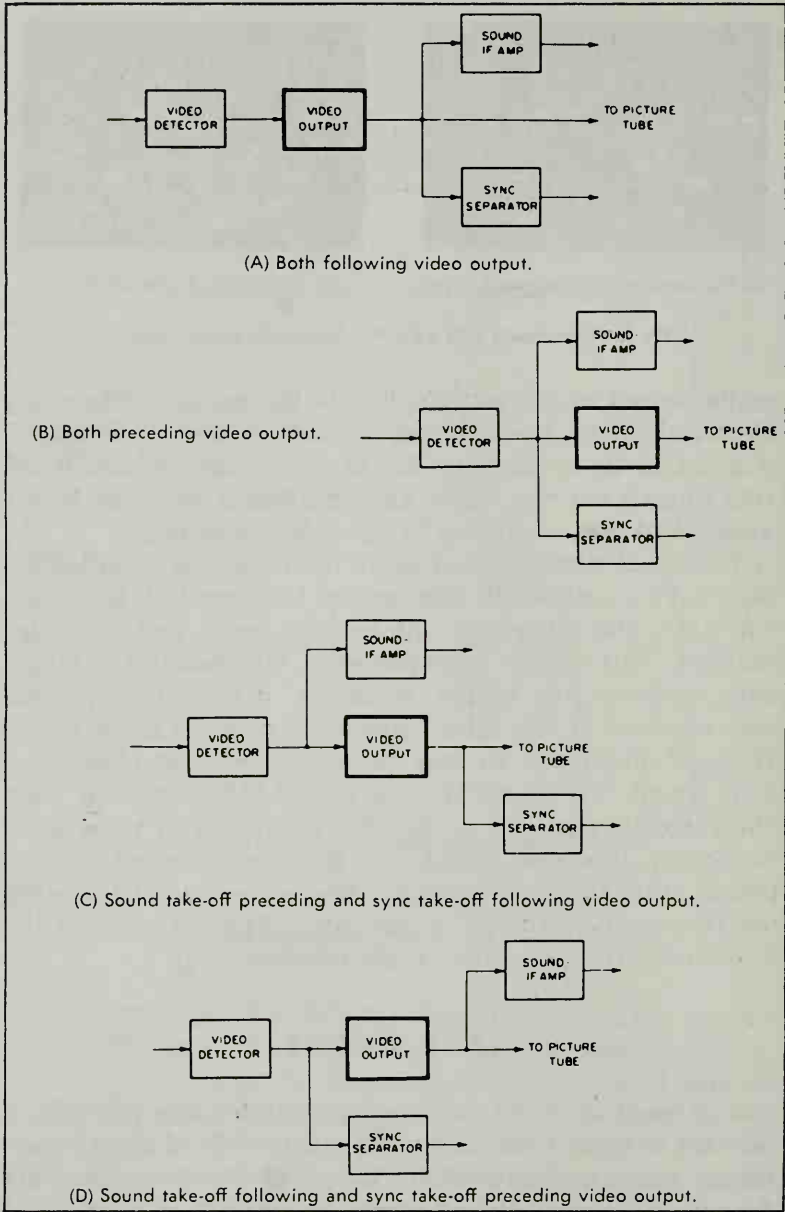(D) Sound take-off following and sync take-off preceding video output.

Fig. 10. Four methods of sync and sound take-offs.

AGC (automatic gain control) keying tube. This stage sam-
ples the amplitude of the signal and produces a bias voltage
for the RF and video-IF amplifiers. This bias voltage con-
trols the gain of these stages so that the output signal is
fairly constant, even though the input signal varies in
strength.

In the keyed AGC system, the amplitude of the video
signal is checked only during the period of the horizontal
sync pulse. Unlike the video signal, the horizontal sync
pulse is always transmitted at a constant level. Thus, keying
the AGC voltage to the horizontal sync pulse provides a
constant check point. The plan of a keyed AGC system
is shown in Fig. 11.

In other systems, no keying pulse is used. In this type
of circuit, the entire video signal is used as the reference.
The tube is then called an AGC amplifier. Sometimes, no
tube is used in the AGC circuit. In these cases, a combi-
nation of resistors and capacitors provide the AGC voltage.

An AGC clamper stage is also shown in dashed lines in
Fig. 3, indicating that it may not be used in all receivers.
This stage removes the AGC voltage from the RF amplifier,
allowing it to operate at full gain until the signal reaches a
predetermined level. When this level is reached, the tube
cuts out and allows the normal AGC voltage to be applied
to the RF amplifier. An AGC clamp is also shown in Fig. 11.

SYNC CIRCUITS

Up to this point, nothing has been said about deflection
in this chapter. We now have the video (picture) signal
displayed on the screen, and sound emerging from the
speaker. In addition, a means has been provided for varying
the gain of the receiver so that we have a nearly constant
amplitude signal at the picture tube. Now, some means
must be provided to deflect this beam back and forth and
up and down on the screen exactly in step with the beam
in the camera tube in the transmitter.
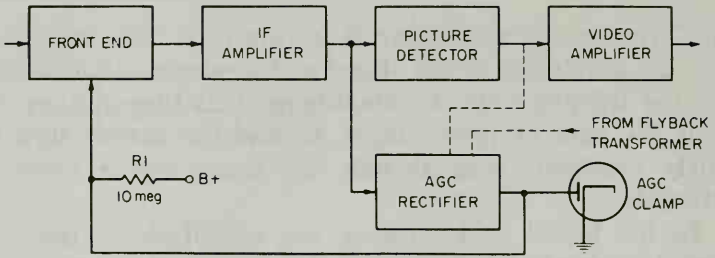
Fig. 11. Plan of a keyed AGC system.

A portion of the video signal at the video output stage is coupled to the sync separator. Here the horizontal and vertical sync pulses are separated from the video signal. From the sync separator, the horizontal sync pulses are coupled to the horizontal deflection circuit and the vertical sync pulses are coupled to the vertical deflection circuit. These pulses serve to start each line or field exactly in step with the beam at the transmitter. A noise-canceller stage is often included to prevent any noise pulses in the signal from being coupled to the deflection circuit and causing improper triggering of these circuits. Fig. 12 shows what is meant by separated or "stripped" sync pulses.

(A) The appearance of the vertical sync pulse or "hammerhead" on the picture tube screen.

(B) Separated or stripped sync pulse.

(C) The build-up of the hammerhead from sync pulse.

(D) The pulses that comprise the hammerhead.

Fig. 12. The stripped sync pulses.

A sync phase inverter may also be included in some receivers. When used, this stage reverses the polarity of the signal so that it will be the proper phase to trig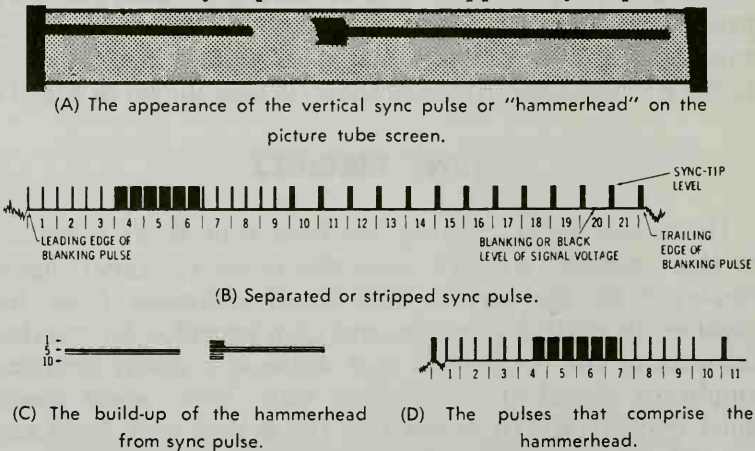ger the deflection circuits. Fig. 13 shows a block diagram of a horizontal automatic frequency control (AFC) and deflection system.

DEFLECTION CIRCUITS

The vertical sync pulses are coupled to the vertical oscillator. The vertical oscillator generates a signal at the 60-cycle vertical deflection rate. The sync pulses trigger the vertical oscillator so that each cycle will start exactly in step with the transmitted signal.

The output of the vertical oscillator is coupled to the vertical output stage where it is boosted in amplitude to the proper level to provide vertical deflection of the electron beam.

The horizontal sync pulses are not coupled directly to the horizontal oscillator. Instead, they are first sent to the horizontal AFC (automatic frequency control) stage. The AFC tube then provides a correction voltage for the horizontal oscillator to keep it exactly in step with the horizontal scanning rate at the transmitter. The primary purpose of the AFC stage is to provide greater immunity to noise pulses which might enter with the horizontal sync pulses.

Like the vertical circuit, the horizontal oscillator generates a signal which is amplified by the horizontal output stage. The amplified signal is coupled to the horizontal deflection coils of the picture tube where it serves to trace the individual horizontal lines across the screen.

The damper tube is shown connected to the horizontal output stage in Fig. 3. During the horizontal retrace period when the beam is returning from the right to the left of the screen, undesired oscillations would be set up in the horizontal-output transformer unless something is done to suppress them. Fig. 14 shows the appearance of ringing bars.
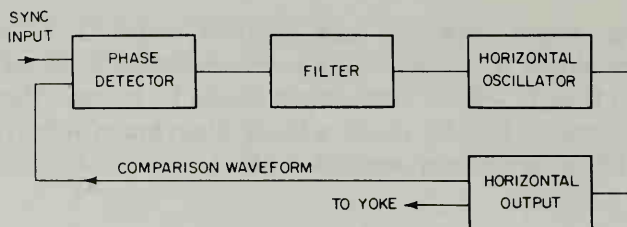
Fig. 13. Block diagram of a horizontal-AFC and deflection system.

The damper tube serves to squelch or clamp out these oscillations. It also permits the deflection coil current to decay at a uniform rate so that the left side of the screen will be linear—that is, not distorted.

Notice, it was stated that both the vertical and horizontal oscillators generated a signal. The sync pulse is not necessary for the stages to operate. The only purpose of the sync pulses is to keep the circuits operating exactly in step with the ones at the transmitter.

POWER SUPPLIES

Two separate power supplies, plus an additional voltage source derived from the damper circuit are used in all television receivers.

Low-Voltage Supply—The low-voltage power supply provides the voltage necessary for operation of practically every tube in the TV receiver. This circuit is much like the power supply of a radio or amplifier. It takes the AC from the line, rectifies it, and supplies the DC B+ voltages necessary to operate the tubes in the TV receiver. Of course, since there are many more tubes in a TV receiver, the TV power supply must be capable of supplying a much higher current than a radio. In addition, the voltage is usually stepped up to a higher value in a TV receiver. Typical B+ voltages in TV receivers range from 125 to 300 volts.

Fig. 14. Ringing bars at the left
side of the raster.
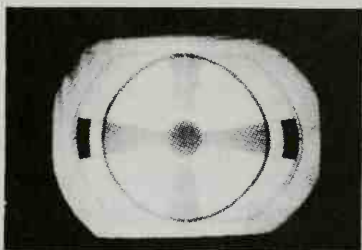
Because all circuits do not require the same operating voltages, a voltage divider is usually connected at the output of the power supply. The different circuits are then connected to the points which supply the proper operating voltages.

In addition to the B+ voltages, the low-voltage supply also furnishes the filament voltage necessary to heat the tubes to the proper operating point and, in some receivers, furnishes negative bias voltages.

High-Voltage Supply—In addition to the B+ voltages, a much higher voltage (15,000 to 23,000 volts) is needed for proper operation of the picture tube. This voltage is obtained from the horizontal deflection circuit. The pulse from the horizontal output stage is stepped up by the horizontal output and high-voltage transformer to a very high value. Then this pulse is rectified by the high-voltage rectifier to provide the high DC voltage. Since very little current is necessary, this high voltage can be obtained from the horizontal output stage without placing too much strain on the stage. Nevertheless, the horizontal output stage is the highest powered stage in the receiver.

Boost Voltage—Another voltage, called the boost voltage, is obtained from the damper stage. The normal damper action of suppressing the pulses in the horizontal output stage results in a voltage higher than the normal B+ being developed in the circuit. This voltage is filtered and put to work in the receiver. In all modern TV receivers, the boost voltage is employed as the B+ for the horizontal output tube. In addition, it may also be applied to the vertical

output, horizontal oscillator, picture tube, and other stages of the receiver.

PICTURE TUBE

Now that all the signals have been properly amplified and processed, let's see what happens at the picture tube (Fig. 15).

The basic operation of the picture tube is the same as for any other tube. That is, a filament (heater) heats the cathode which emits electrons—the same as any tube. These electrons are attracted by the accelerating anodes which have $B+$ voltage on them and by the second anode which has the high voltage connected to it. However, instead of striking these elements, the electrons travel to the face of the tube and strike the screen. The screen is coated with a fluorescent material which glows when struck by the electrons. This is the lighted portion you see on the screen.

The magnetic field from the focusing devices concentrates all the electrons in the beam so they strike the screen at
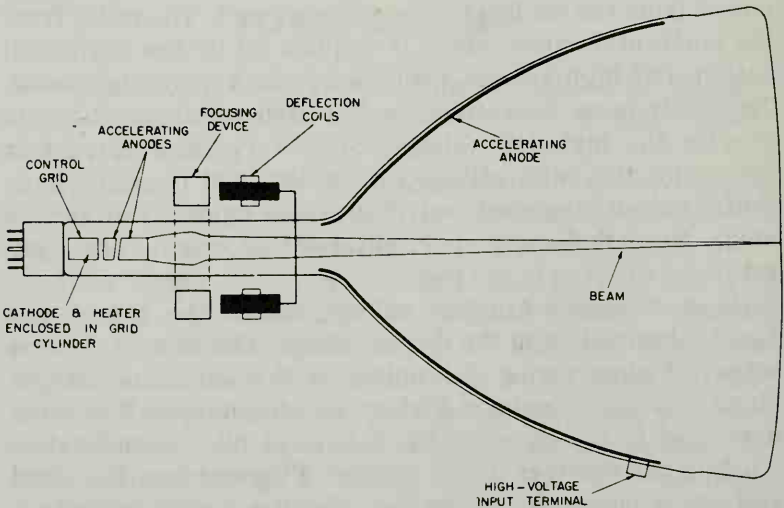
Fig. 15. A magnetically-controlled cathode-ray tube.

one point. A magnetic focusing device, connected around the neck of the tube is shown in Fig. 15. In many receivers, however, this function is accomplished by another element within the picture tube.

The horizontal and vertical deflection currents are applied to the deflection coils shown on the neck of the tube. These currents, flowing through the coils, cause a magnetic

Fig. 16. Overview of basic troubleshooting procedures.

field to be produced which acts upon the electron beam in the tube. These vertical deflection currents cause the beam to be deflected upward or downward from the center of the screen. This deflection is at the 60-Hertz rate. At the same time, the horizontal deflection currents cause the beam to be deflected to the left and right at the 15,750-Hertz rate.
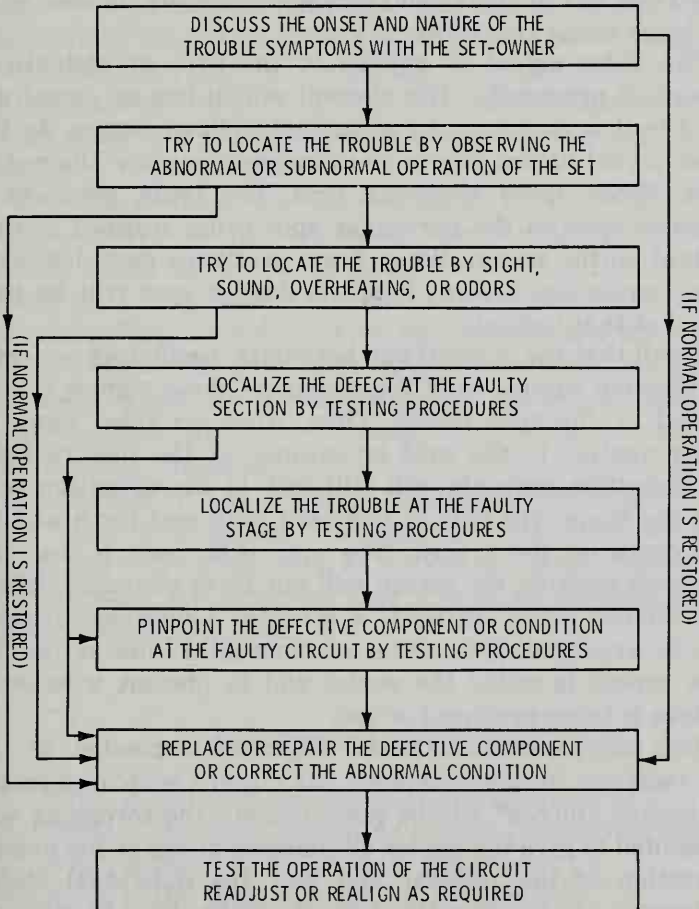
Thus, the beam is caused to scan across the face of the tube from left to right and from top to bottom, in step with the beam at the transmitter.

The video signal is applied to the grid or cathode as explained previously. The element which has no signal applied to it is connected to a constant voltage source. As the video signal varies, fewer or more electrons are allowed to pass. When more electrons pass, the beam produces a brighter spot on the particular spot being scanned at that instant on the screen. When fewer electrons pass, less electrons strike the screen; hence, a darker spot will be produced at that instant.

Recall that the vertical and horizontal oscillators *generate* a deflection signal—only the timing of these signals is controlled by the sync pulses. Thus, when no video signal is being applied to the grid or cathode of the picture tube, the deflection currents will still flow in the deflection coils and the beam will still be deflected back and forth and up and down on the screen. The only difference is that the electrons striking the screen will not form alternate lighter and darker areas. Instead, a constant brightness pattern will be produced. This series of horizontal lines across the tube screen is called the *raster* and is present whether a picture is being produced or not.

This completes the "block diagram" discussion of the TV receiver. In later chapters, the circuits employed in the individual "blocks" will be examined but the foregoing was presented to give the reader an understanding of the overall operation of the receiver and how the individual blocks fit together to produce the desired results. Fig. 16 gives an overview of the basic TV troubleshooting procedures.

SUMMARY

The function of the television receiver is to pick up the signal from the television station, amplify it, and produce a visible picture and audible sound corresponding to the original scene.

In the television receiver, the signal is received, amplified and separated into its individual components. Deflection of the beam in the picture tube is accomplished electromagnetically with coils, external to the tube. The deflection circuits in the receiver are kept in step with the deflection circuits in the camera by the sync pulses transmitted as part of the composite video signal.

The signal from the desired VHF or UHF television station arrive at the television receiver antenna. These signals travel down the antenna line to the RF amplifier where only the desired signals are selected and rejects all others. The desired signal is amplified by the RF amplifier and coupled to the mixer. In the mixer stage the amplified signal from the RF amplifier and the signal from the local oscillator are beat together to produce a lower, or intermediate frequency.

The output of the mixer is coupled to the input of the first video IF amplifier. The signal at this point still contains both video and sound, as well as the sync signals. The IF amplifiers are tuned to pass a band of frequencies approximately 4 MHz wide.

REVIEW QUESTIONS

1. What is the purpose of the television receiver?
2. Explain the basic operation of the television receiver.
3. What is the typical video IF frequency?
4. What is the typical sound IF frequency?
5. What separates the sound present in the video-IF amplifier?

6. What is meant by *intercarrier?*
7. What is the purpose of the low-voltage and high-voltage supply?
8. Where is the source obtained for high-voltage?

Television Receiver Placement and Adjustment

The proper placement of a television receiver, of course, depends upon such factors as the layout of the house, number and size of the individual rooms, the lighting arrangement, location of power outlet, antenna lead-in, etc.

In some cases, the type of power outlet is a matter of importance. For example, most receivers may be plugged into switched or unswitched outlets. On the other hand, an "instant-on" type of receiver should always be operated from an unswitched outlet. Otherwise, possible damage may result from successive "cold-start" cycles. Again, some receivers provide digital readout, with channel number and the time displayed on the screen when so commanded. (See Fig. 1). The digital clock should always be operated from an unswitched outlet. Otherwise, the indicated time is likely to be in error.

1. Do not place the receiver in such a position that direct illumination, such as light from a window, falls directly on the face of the screen. A certain amount of background illumination is desirable when viewing over long periods of time to reduce eyestrain.

2. Do not place the cabinet directly against the wall. Leave a two-inch air space so that adequate ventilation will be assured. In addition, the receiver must
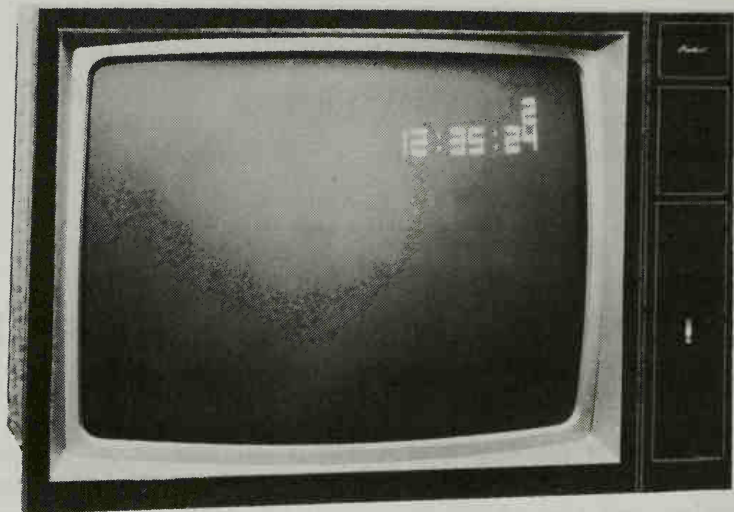
Courtesy Heath Co.

Fig. 1. Example of digital television receiver that provides time and channel number readout on the screen.

   be installed a sufficient distance from any heating
   device such as heating radiators, etc., as the effect of
   heat will impair its operation or even damage the
   receiver.

3. It is desirable to locate the receiver as far as possible
   away from sparking or gaseous electrical discharge
   devices such as neon display signs, electrically oper-
   ated cash registers, etc.

4. If the receiver is to be connected to an outside an-
   tenna, proper attention should be given to the location
   of the antenna lead-in and the power outlet to pre-
   vent excessive length of these connector leads. A
   typical receiver location is shown in Fig. 2.
   With respect to the decorative scheme of the home, most
decorative authorities agree on the following points:

1. The room containing the television receiver should be so planned that viewers can enjoy a program without first upsetting and rearranging the room.
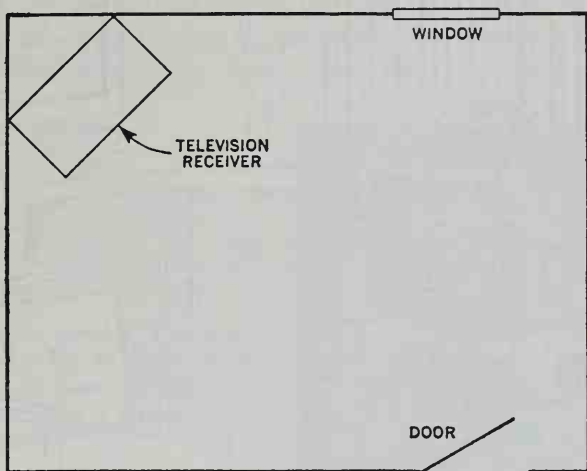

Fig. 2. A typical receiver location. When selecting location, keep in mind the necessity of an electrical outlet and, if necessary, the external antenna and transmission line.

2. Lighting should be arranged so as to prevent the light from shining directly on the screen or in the viewers face.

3. The television receiver should not be so dominant in design or location that viewers have to sit and face it when not in use.

Other factors such as seating arrangements, type of chairs, stools or hassocks to use, and their individual characteristics of comfort and convenience must be left to individual taste and suitability. Some owners prefer to have their principal receiver placed in a corner of the living room while others prefer to have it (or a second receiver in the family room, den, library, or study if such are available). Some prefer to have the receiver built into a room divider or bookcase as
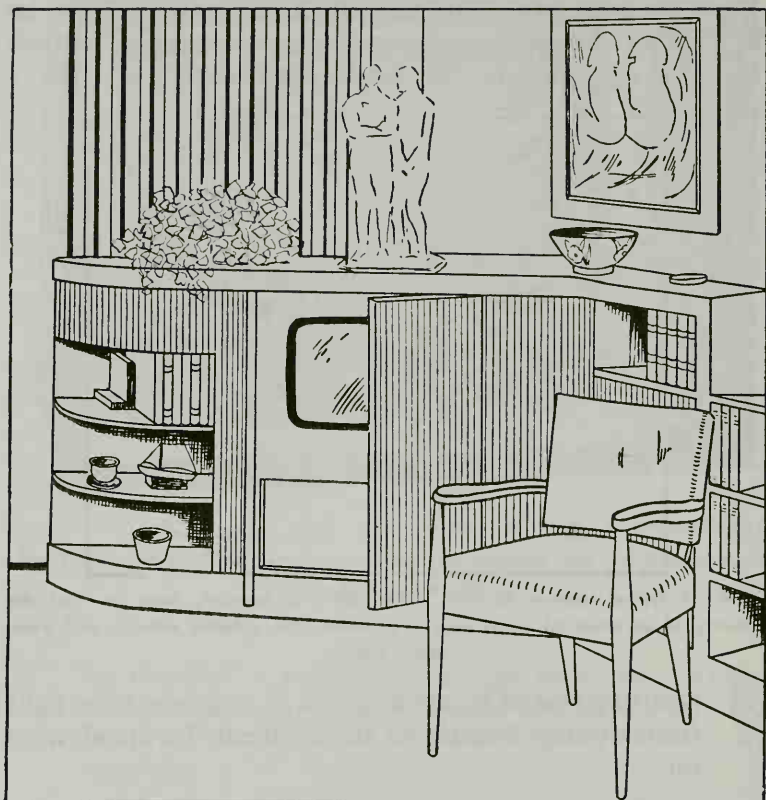
Fig. 3. A built-in television receiver. Here the wall unit serves as television cabinet, bookcase, and room divider.

shown in Fig. 3. Here, when the set is not in operation, the door can be closed.

In recent years, a second or third receiver has been added to many homes. Children's rooms, basement recreation rooms, and kitchens are popular locations for an additional receiver. Often a portable receiver (Fig. 4) which can be rolled or carried anywhere in the house, or even outdoors wherever power is available, is employed. Some portable receivers are completely transistorized (except for the picture

tube, of course), operate on self-contained batteries, and can be carried anywhere.

Television Lighting.—In the early days of television, many people would turn out all the lights and sit in the dark watching the bright spot of the television receiver on the other side of the room. Soon, the eyestrain from such a

Fig. 4. A typical portable TV receiver. Such a receiver can be easily moved to any desired location, provided an electrical outlet is available.
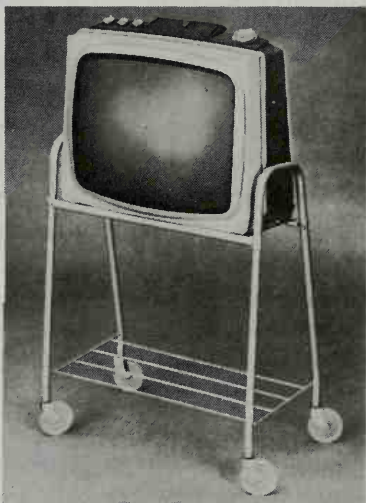
setup became apparent and all types of special TV viewing lights made their appearance. Improvement in the viewing screen of television picture tubes and education of the viewing public soon made all of this unnecessary. All that is necessary is to make sure that the lighting (either sunlight or artificial) does not cause a glare on the screen or shine in the viewers' eyes while they are watching the receiver.

TELEVISION CONTROLS

Any piece of electronic equipment must have provisions for adjustment before proper operation can be obtained. The television receiver is no exception—every television receiver
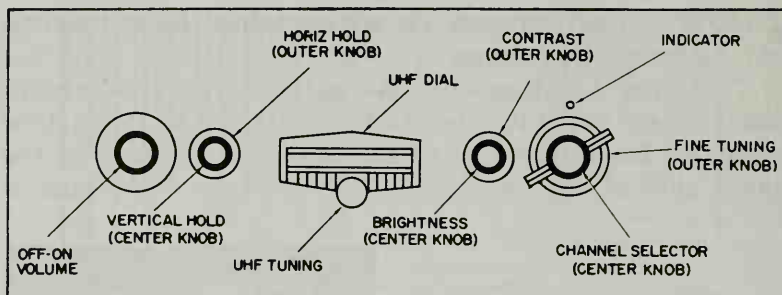
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Fig. 5. Typical operator controls.

contains several controls which are varied to obtain the proper reproduction of the picture and sound transmitted by the station. Operator controls are depicted in Fig. 5.

Some adjustments must be varied more often than others; hence manufacturers place some controls on the front, side, or top of the TV cabinet where they are readily accessible to the operator. Other controls require less frequent adjustments, so they are located on the rear panel of the chassis, the chassis itself, or on the neck of the picture tube. The readily accessible controls are termed *operator controls*, while the others are called *service adjustments*. Manufacturers differ, however, in the number and type of controls they include for operating controls and the ones which they make service adjustments. In addition, depending on the chassis design, some receivers will contain controls that are not on others. Also, the terms used to identify the same control vary. For example, some manufacturers may call the control that varies the shading of the picture the *contrast control*; others may call the identical control the *Picture,*

Fig. 6. Typical service adjustments.

Picture Power, or *Shading* control. Typical service adjustments are depicted in Fig. 6.

In general, however, the operating controls affect the program selection and the picture and sound quality, while the service adjustments (also called preset controls) affect picture quality, position, or spacing.

The following controls are most often placed as operating controls, however; as mentioned previously, all of these controls will not be accessible in all receivers:

1. On-off switch and volume control.

2. Tone control.

3. Channel selector.

4. Fine-tuning control.

5. Contrast control.

6. Brightness control.

7. Horizontal-hold control.

8. Vertical-hold control.

Most of these controls will not need adjustment during normal reception; however, they require more frequent adjustment than the other controls. As receiver design improves, these controls require less frequent adjustment, so they may be moved to the rear of the chassis. For example, the last three controls listed in the foregoing are not included as operator controls by many manufacturers.

Dual Controls—In order to simplify the operation and to improve the appearance of the cabinet, dual controls, with concentric knobs, are often employed. That is, the controls are arranged in pairs of two; a small inner knob and a larger outer knob each affecting only one-half of the dual control are used. For example, the *channel-selector*
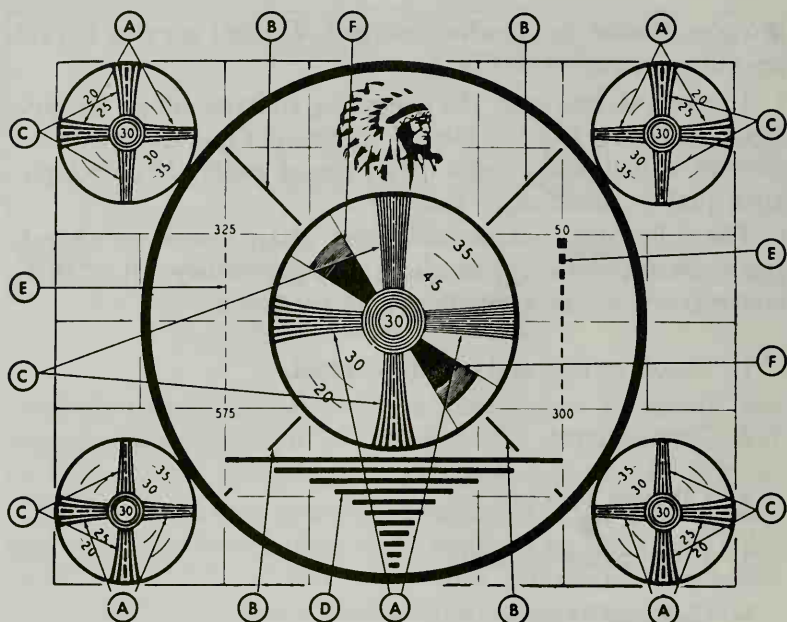
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Fig. 7. Indian-head test pattern. Such patterns are very helpful in setting up a TV receiver.

and *fine-tuning* are commonly dual knobs. The *contrast* and *brightness* controls and the *volume* and *tone* controls are often similarly arranged.

Some manufacturers arrange some of the controls behind a hinged panel. At other times, some of the controls may be located beneath the knobs of other controls. In this case, the knob must be removed before access can be gained to the concealed controls. A screwdriver is usually needed to adjust these concealed controls. Controls which are included behind covers or knobs do not need to be reset each time the receiver is operated, so their lack of accessibility is more than compensated for by the improvement in appearance.

THE TEST PATTERN

Before the operation and proper adjustment of the various controls can be understood, the test pattern and the part

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it plays in adjustments, must be understood. Fig. 7 is a standard test pattern. Many TV stations transmit a pattern similar to this before they begin transmitting regular pro-
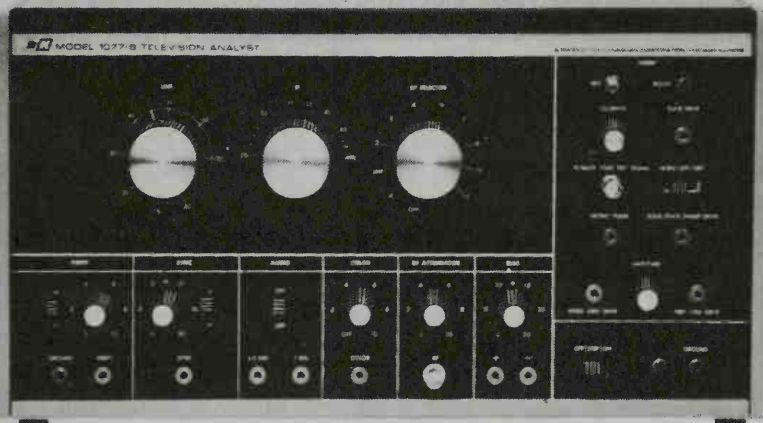
Fig. 8. A service-type pattern generator.

grams for the day. Such patterns are also available from pattern generators—a piece of test equipment. (See Fig. 8). Station test patterns usually will not include all of the features of the one in Fig. 7, and they will include station identification, but most of the features in Fig. 7 will be recognized in a station test pattern. When a station is transmitting a test pattern, the sound will consist of a single tone transmitted continuously. Many stations begin their programs so early in the day that they do not transmit a test pattern.

The function of a test pattern is to furnish an accurate means of comparing the picture that appears on the picture tube with that seen by the television camera. If the two are identical, it would indicate completely perfect transmission and reception throughout the entire system. Such a condition of course, is impossible to accomplish; however, it can be very closely approximated.

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Such factors as *aspect ratio, resolution, linearity, contrast, brightness*, and *focus* can be easily checked using the pattern in Fig. **7**.

Aspect Ratio—The *aspect ratio* of a picture determines its proportions. The television standards followed by all U.S. television stations state that the aspect ratio shall be 4:3, which means that the width is 4/3 times the height of the picture. Stated in the opposite manner, it means that the distance from the top to the bottom of the picture should be 3/4 the distance from the left to the right side of the picture. The faint vertical and horizontal lines across the pattern in Fig. **7** can be used to determine the aspect ratio. Notice there are 8 such vertical lines and 6 horizontal lines. Thus, the picture is divided in 8 parts horizontally and 6 vertically giving an aspect ratio of 8:6 or 4:3.

Resolution—The term *resolution* means the extent to which the details of the televised picture are separated. *Vertical* resolution is determined by the number of separate and distinct horizontal lines that the system can reproduce. It depends largely on the following:

1. The number of scanning lines employed.

2. Size of the scanning beams in both the camera tube and the picture tube.

3. Sensitivity of the camera tube, and other elements of the transmitting apparatus.

A check on the vertical resolution can be made by observing the horizontal wedges at each corner and in the center of the test pattern is Fig. **7** (indicated by the letter A). Vertical resolution is determined by the number of separate individual horizontal lines that the system is capable of reproducing from the top to the bottom of the screen. To determine the vertical resolution, look at the horizontal wedges (A) and note the point where the lines are no longer

separate and distinct. The breaks in the center line of the wedge indicate 50-line intervals. These 50-line intervals are indicated by the numbers placed diagonally within the circle, except that the last zero is omitted. For example, if the lines tend to merge together at the break opposite the 35, the vertical resolution is 350 lines.

The vertical wedges at the center and each corner (indicated by the letter C) are used to check horizontal resolution or detail. The amount of detail is determined by the number of separate and distinct vertical lines side by side that can be reproduced. The horizontal detail at each break in the center line is shown at 50-line intervals as explained for the horizontal wedge.

Linearity—*Linearity* refers to the uniformity of distribution of the pattern on the screen. When the conditions of the electron beam in the picture tube are such that the beam does not move at constant speed, the objects in the picture will be distorted in shape. As a result, the picture is said to have poor linearity.

Both vertical and horizontal linearity can be checked by observing the black circles in the pattern. If perfect linearity is present, the circle is geometrically flawless. If it is distorted at the top or bottom, vertical nonlinearity is present. If the sides are distorted, horizontal nonlinearity is present.

Brightness and Contrast—Brightness and contrast must be present in suitable proportions for a pleasing picture. Brightness without adequate contrast actually reduces the clarity of the picture. Contrast depends upon the amount of change of the video voltage applied to the picture-tube grid; that is, its peak-to-peak swing. In other words, the contrast control affects the picture in the same manner as the volume control affects the sound. Brightness of the picture depends upon the DC or average value of the video signal at the picture tube.

The correctness of the contrast and brightness control setting can be checked by the shaded wedges which extend

diagonally from the upper left to the lower right near the center of the test pattern (labeled F) and the Indian Head at the top. The wedges contain different shades ranging from light gray to black. When the brightness and contrast control are properly set, distinct differences in shading should be noted for each step.

Focus—The test pattern in Fig. 7 can also be used to check for correct focus. Observe the pattern to see if the image is sharply defined. If each element of the pattern is sharp and crisp, the focus is correct; however, if the image appears blurred and the lines are fuzzy, improper focus is indicated.

Interlace—Proper interlace is determined by observing the diagonal black lines labeled B in Fig. 7. Poor interlace causes these lines to become jagged. When interlace is proper, the lines are sharp and straight.

OPERATOR CONTROLS

The operator controls for three typical modern television receivers are shown in Figs. 9, 10, and 11. The receiver shown in Fig. 9 is typical of VHF-UHF receivers. It has

VHF TUNING
VHF FINE TUNING
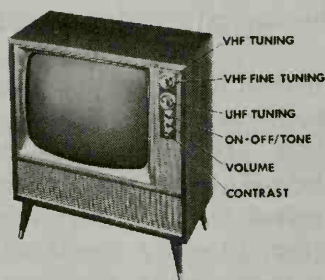UHF TUNING
ON-OFF/TONE
VOLUME
CONTRAST

Fig. 9. Operating controls of a typical VHF-UHF receiver.

separate knobs for tuning the VHF and UHF channels. In addition, tone, volume, and contrast controls, as well as the on-off switch, are included as operator controls. The number of operator controls on other receivers will vary from

those in Fig. 9. For example, the one shown in Fig. 10 includes many controls that are normally service adjustments while the one in Fig. 11 contains only 3 controls—the channel selector, fine-tuning control, and on-off switch and volume control.
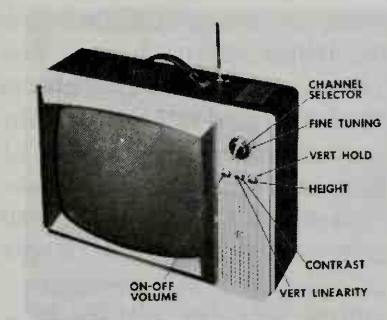

Fig. 10. A receiver with more than the normal number of operating controls.

Fig. 11. A portable receiver with a minimum of operating controls.

As mentioned previously, the operator controls may require adjustment each time the TV set is turned on although most will not. The most popular operator controls, and their function, are as follows:

On-Off Switch and Volume Control—The purpose of the on-off switch and volume control is to turn the receiver on and off and to adjust the sound volume to the desired level. Notice that in Fig. 9, the on-off switch was located on the tone control, but the on-off switch is usually included with the volume control.

Tone Control—The tone control is used to select the desired amount of bass and treble tones. Once this control is adjusted to suit the individual listener's taste, it usually will not require further adjustment.

Channel Selector—This control consist of a simple selector switch by means of which the correct channel number of the desired station can be selected. The channels presently employed are numbered 2 through 83. Some receivers only tune the VHF channels (2 through 13), and others have a

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separate tuning knob for the UHF channels (14 through 83) as was shown in Fig. 9.

Fine-Tuning Control—This control tunes the receiver for best sound and picture. After the proper channel is selected, adjust the fine-tuning control to obtain the best picture quality. In sets employing preset fine tuning, this control can be set for each channel when the set is installed and will seldom need readjustment. Other receivers may not include a fine-tuning control. Such sets require touch-up adjustment of the oscillator slugs (described later) to obtain the best picture.

Contrast Control—A variation in the amount of background light or picture shading is provided by this control. Adjust for correct contrast between light and dark areas of the picture.

Brightness Control—This control sets the picture brilliance, or the overall brightness of the screen. If the brightness control is set too high, the picture appears "washed out" and bright diagonal retrace lines may appear on the screen as shown in Fig. 12. The contract control should be used with
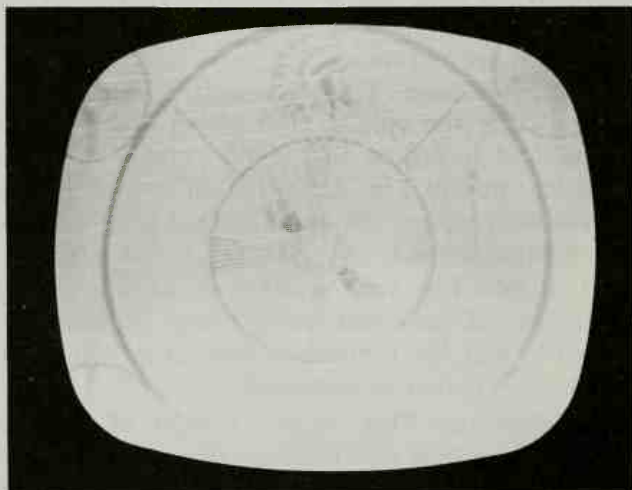

Fig. 12. Test pattern showing the effect when the brightness control is set too high.

the brightness control to obtain the best contrast and brightness ratio.

Horizontal-Hold Control—The horizontal-hold control is an adjustment of the horizontal synchronization circuits. Misadjustment of this control will cause the picture to move either right or left or, in extreme cases, it will cause black-and-white horizontal bars to appear on the screen as shown in Fig. 13. This control should be adjusted until the picture appears, is centered, and there is no horizontal movement.

Vertical-Hold Control—When switching from a strong to a weaker station, it may sometimes be necessary to readjust the vertical-hold control. Misadjustment of this control will cause the picture to roll up or down as shown in Fig. 14. This control should be adjusted so that there is no vertical movement in the picture.

STEP-BY-STEP TUNING PROCEDURE

In order to select a particular station and to adjust the various controls for correct picture and sound reception, proceed as follows:

1. Turn the volume control about one-half turn clockwise. This supplies power to the receiver. Allow a short while for the tubes to reach operating temperature.

2. Turn the channel selector so that it indicates the number of the desired station channel.

3. Turn the fine-tuning control for best detail of the picture and good sound.

4. If necessary, adjust the horizontal and/or vertical hold controls to properly synchronize the picture.

5. Adjust the contrast and brightness controls to obtain the proper shading and overall brightness in the
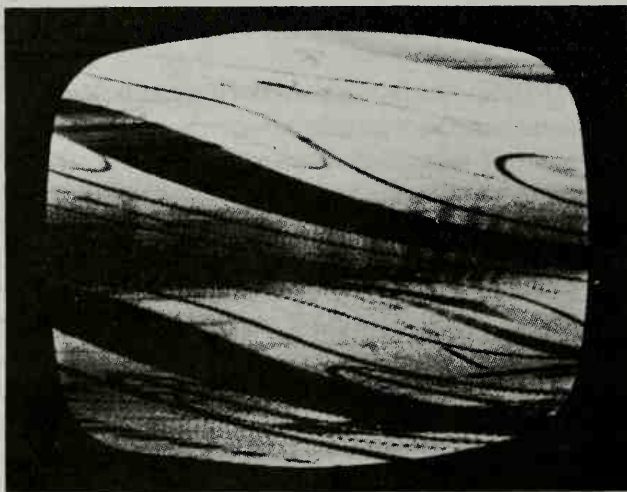
Fig. 13. Test pattern showing the horizontal-hold control misadjusted. The more the horizontal hold control is misadjusted, the more diagonal bars appear. As the adjustment approaches the correct setting, fewer bars appear.

picture. That is, it should have good deep blacks, whites, and intermediate shades of gray.

6. Readjust volume for most pleasing reproduction.

After the receiver has been adjusted as indicated, the volume control need only be used to turn the receiver *on* or *off* between the desired programs unless some other station is to be tuned in.

PRESET OR SERVICE ADJUSTMENT CONTROLS

The preset or service adjustments are factory adjusted for optimum performance; however, it is usually necessary to make some adjustments of them at the time of installation. The service adjustment controls usually consist of the following:
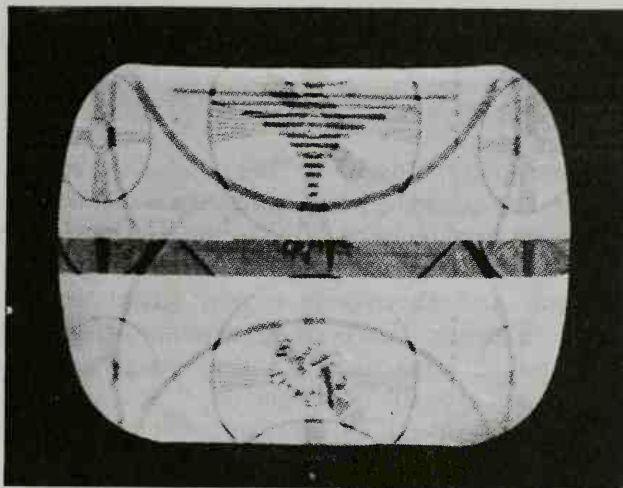
1. Focus control.

Fig. 14. Test pattern showing the vertical-hold control misadjusted. As the correct adjustment is approached, the pattern moves slower and slower until it locks in position.

2. Vertical size (height).

3. Vertical linearity.

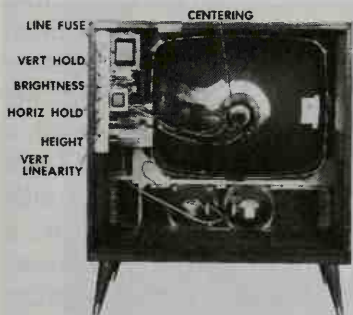4. Horizontal size (width).

5. Horizontal linearity.

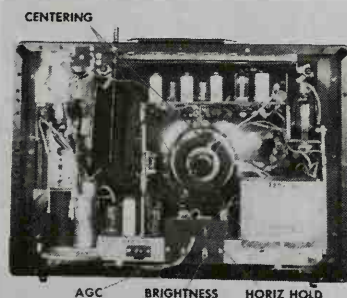Fig. 15. Rear view of the TV receiver pictured in Fig. 7.

Fig. 16. Rear view of the TV receiver pictured in Fig. 8.

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6. AGC.

7. Buzz.

Depending upon the design of the receiver, some of these controls may be located at the front or side of the cabinet, whereas others may be located in the rear of the chassis. In addition, all of the controls may not be included in all receiver designs, and other receivers may include controls not listed in the foregoing. Three arrangements for service controls are shown in Figs. 15, 16, and 17. In other receivers, other arrangements will be employed.

Focus Adjustment—If the various elements in the picture are not sharp and crisp but appear blurred and printing is difficult to read, the focus should be adjusted. Proper
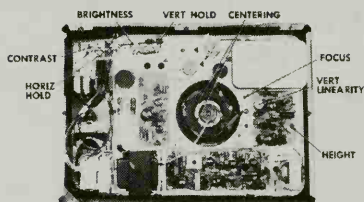

Fig. 17. Rear view of TV receiver pictured in Fig. 11.

focus is obtained by looking at the horizontal scanning lines which make up the picture and adjusting for minimum width of the lines. Various means are employed for adjusting the focus. Some receivers have a control on the rear panel which is rotated until the best focus is obtained. In others, a screwdriver adjustment or a flexible shaft extending from the focus unit around the neck of the tube is adjusted until proper focus is obtained. In still another arrangement, a terminal strip which provides a choice of 3 or 4 different voltages is located on the chassis. A lead from the picture tube socket is connected to the terminal which gives the best focus. Usually a clip arrangement is provided to facili-
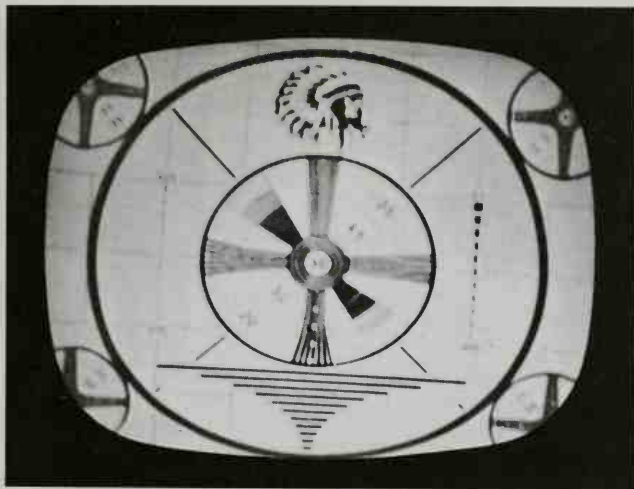
Fig. 18. Test pattern showing the effect of a misadjusted focus control.

tate this connection. The result of an improperly adjusted focus control is shown in Fig. 18.

Height and Vertical Linearity Control—These controls should both be adjusted at the same time and preferably
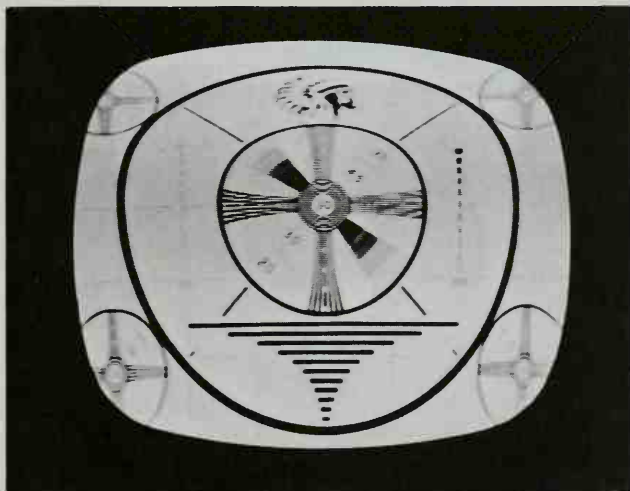

Fig. 19. Test pattern showing the effect of misadjustment of the vertical linearity control.
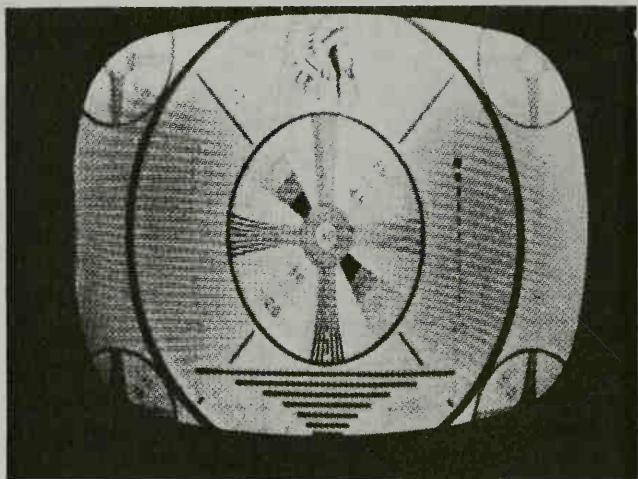
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Fig. 20. Test pattern showing the effect of a misadjusted height control.

while a test pattern is being transmitted. The linearity control affects the upper portion of the picture (Fig. 19) while the height (size) control primarily affects the lower portion but also affects the overall picture (Fig. 20). Adjust
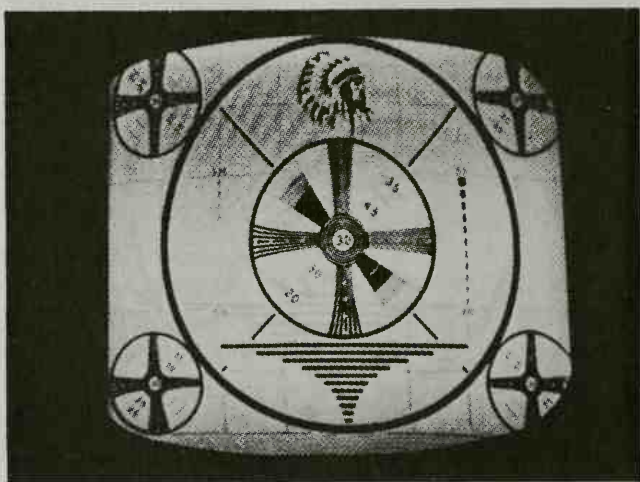

Fig. 21. Test pattern showing the effect of a misadjusted width control.

both controls simultaneously until the test pattern is symmetrical and fills the entire screen vertically. Readjust the vertical hold control if necessary.

Width Control—Control of picture size in the horizontal direction is accomplished by means of the width control. If the picture does not fill the screen horizontally (Fig. 21), adjust the control until the picture fills the screen. If an abnormally low line voltage makes it difficult to obtain sufficient picture width using the width control, changing the horizontal drive control (if present) may prove helpful. Note, while the width control may be an ordinary variable-resistance control, it is often the slug in a variable inductance. In other receivers, a plastic sleeve with a piece of copper embedded in it is inserted between the neck of the picture tube and the deflection yoke. The width is varied by sliding the sleeve in and out on the neck. In still other receivers, no width control is included.

Horizontal Linearity Control—This control should be adjusted for best possible horizontal linearity. In the event that proper horizontal linearity (Fig. 22) cannot be obtained
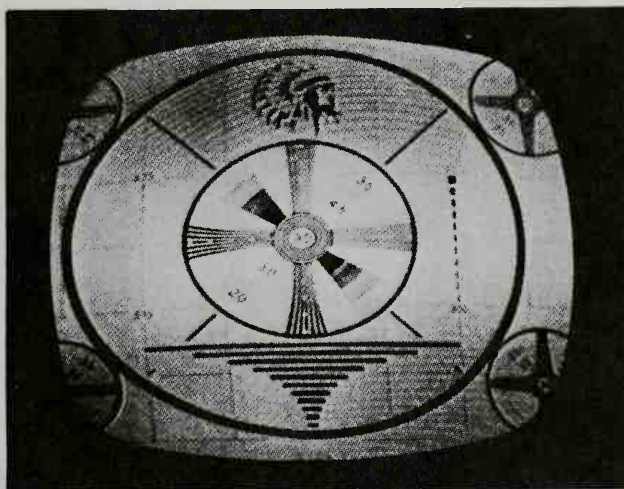

Fig. 22. Test pattern showing the effect of misadjustment of the
horizontal-linearity control.

by adjusting this control, then change the setting of the horizontal drive and/or width control. Like the width-control, the linearity control is most often the slug of a variable inductance. In other systems, no control as such is included, but linearity is adjusted by changing the position of small magnets which extend from the neck of the picture tube. In still other receivers, no provisions are included for adjusting the linearity.

Horizontal Drive Control—Misadjustment of the horizontal drive control (not included in many chassis) results in the symptoms pictured in Fig. 23. If white vertical bars, black beaded lines, or foldover appears in the picture, the drive control should be adjusted.

AGC Control—Many receivers contain some type of AGC control. Many names are used for such controls, but all perform essentially the same function. In some receivers, a variable-resistance control may be employed; in others a two- or three-position switch is used. When the AGC control is misadjusted, the symptoms can range from a weak snowy picture to an overloaded one. (In an overloaded
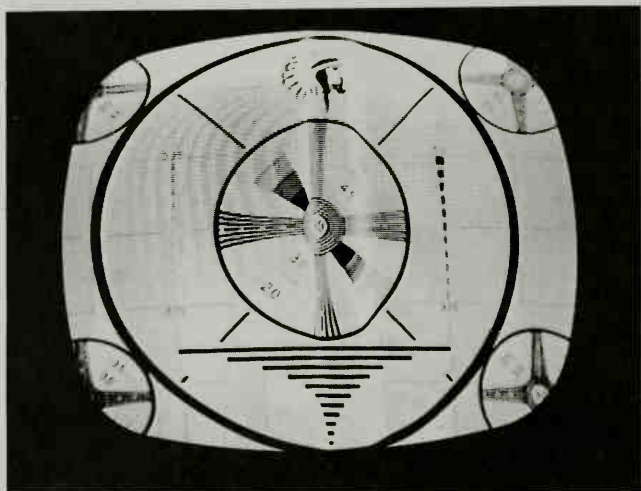

Fig. 23. Test pattern showing the effect of misadjustment of the horizontal-drive control.

picture everything is much darker than normal, and partial or complete loss of horizontal or vertical sync may occur. Often, these symptoms are accompanied with a buzz in the sound.) The AGC control should be set to produce the best picture quality. Correct setting may change with picture strength.

Buzz Control—With some types of sound circuits, there is a possibility of the synchronizing signals causing a 60 Hertz buzzing sound in the audio. Therefore, a control (called the buzz or quieting control) is usually included to eliminate the buzz when this type sound circuit is employed. The control is correctly adjusted when no buzz is heard from the speaker.

Straightening Tilted Raster—This condition (Fig. 24) makes the test pattern or picture appear in a slightly tilted position. The remedy consists of rotating the yoke until the situation is corrected. In some receivers (Fig. 25) a thumbscrew must be loosened before the deflection yoke can be rotated. This locking screw should be retightened after the operation. In others (Fig. 26) no locking screw is employed.
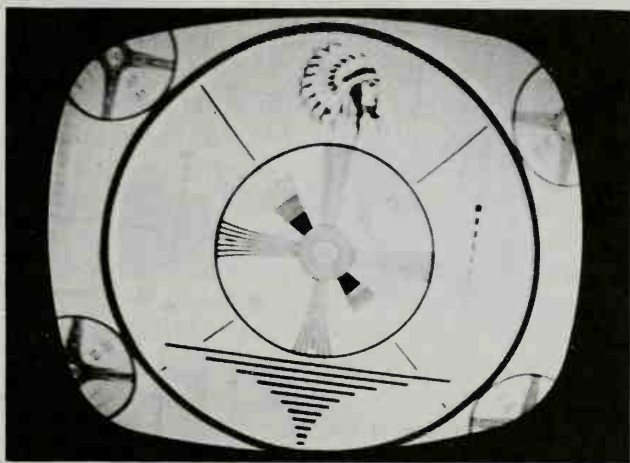
Fig. 24. Test pattern showing the effect of a misadjusted deflection yoke.

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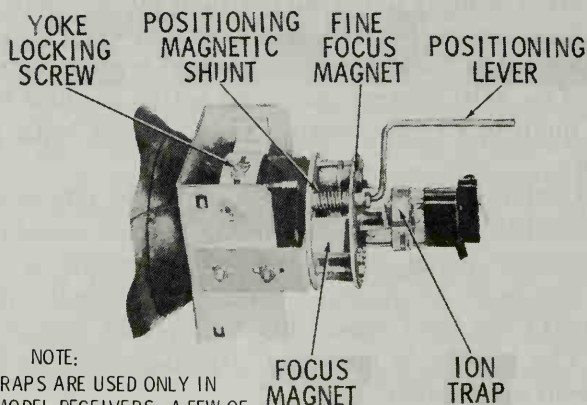
Fig. 25. Neck of a picture tube in a TV receiver which employs a deflection yoke with a retaining screw and a permanent-magnet focus device with positioning lever.

Centering—Fig. 27 shows a test pattern with the horizontal centering misadjusted. A similar condition will exist when the vertical centering is misadjusted except, of course,
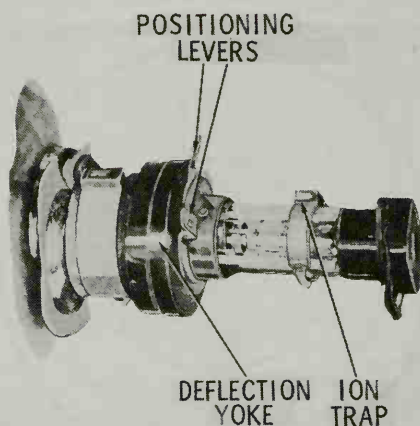

Fig. 26. Neck of a picture tube in a TV receiver which employs an unsecured deflection yoke and two magnetized rings for a centering device.

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the blank space will be at the top or bottom of the screen (Fig. 28). The centering adjustments will be located on the rear panel of the chassis or on the neck of the picture tube. In some early receivers, two controls—labeled *vertical centering* and *horizontal centering* were located on the rear of the chassis. These controls are rotated until the picture
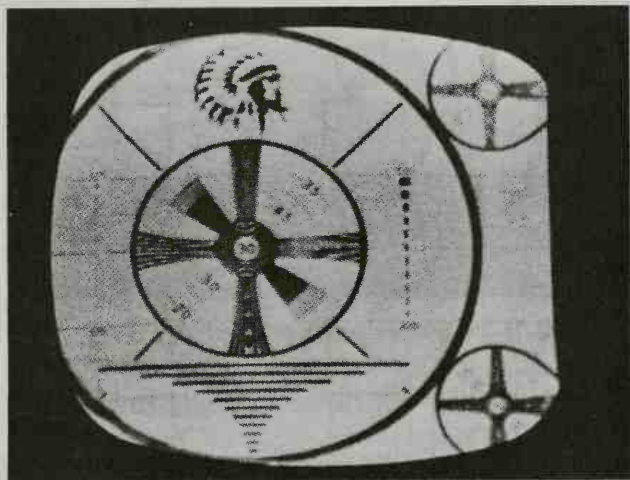
Fig. 27. Test pattern showing incorrect horizontal centering.

is properly centered. (Note: the width and height controls may need readjustment after the picture is properly centered.) In another method, centering is accomplished by moving a positioning lever attached to a magnetic shunt in the focus coil (Fig. 25). This lever is used for both horizontal and vertical adjustments. Still another method employs a tab which extends from the top of the focus coil and is secured with a thumbscrew. To adjust this type arrangement, loosen the thumbscrew and move the tab up and down and to the right and left until the picture is properly centered.

In the most popular centering arrangement for modern TV receivers, two magnetized rings are included on the neck of the tube as shown in Fig. 26. These rings have

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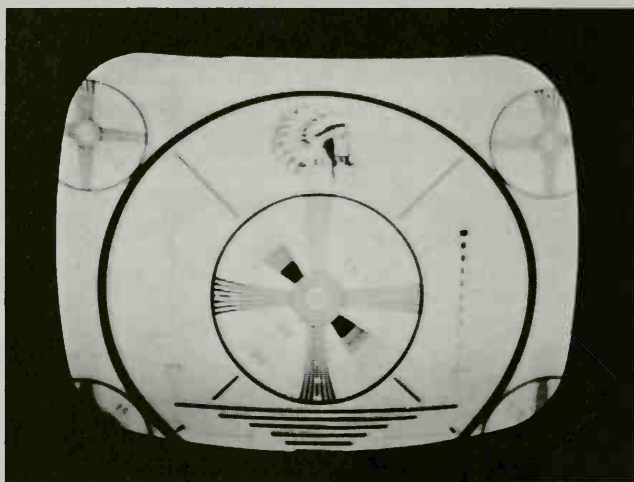
Fig. 28. Test pattern showing incorrect vertical centering.

tabs attached to them which are rotated until the picture is properly centered.

In each of the centering methods employing adjustments on the neck of the tube, there is a certain amount of interaction between the adjustments. Work slowly and carefully until you "get the feel" of the adjustment. *Extreme care* should be employed to be sure that you do not place undue strain on the neck of the picture tube.

Eliminating Semicircular Shadows—This shadow (Fig. 29) is caused by the electron stream striking the neck of the tube. If the condition cannot be corrected by adjusting the centering controls, it can usually be corrected by applying one or a combination of the following procedures:

1. Make sure that the deflection yoke is positioned as far forward as possible.

2. Reposition the focus coil by readjusting the holding nuts to shift the coil forward.
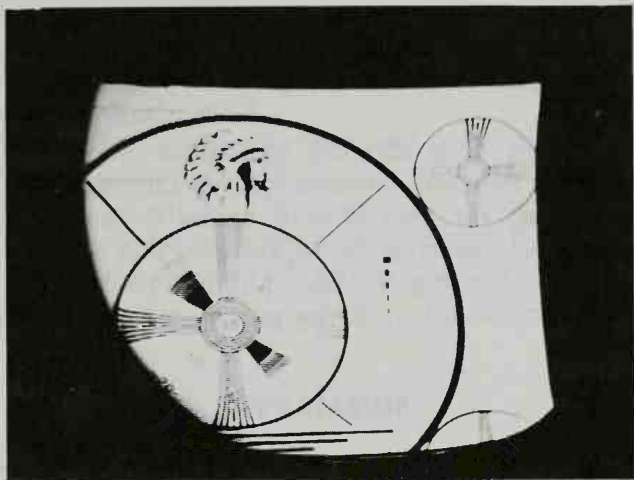
Fig. 29. Test pattern showing neck shadow caused by an improperly adjusted centering control.

3. In the event the neck shadow cannot be eliminated by the foregoing procedure, raise or lower the entire yoke and focus-coil assembly so that the focus coil can be repositioned vertically with respect to the tube neck.

The Ion-Trap Magnet—An ion trap, which consists of a permanent magnet fitted on the neck of the picture tube, is employed in old-model TV receivers. The purpose of this unit is to prevent ions, which are molecules of matter in the electron beam that have been excited by electron bombardment so as to have a negative charge, from striking the face of the picture tube. If allowed to remain in the electron beam, the ions will eventually cause a dark spot in the center of the picture tube face. There are numerous types of ion traps, all differing in appearance but identical in action. An ion trap is shown in both Figs. 25 and 26.

The ion-trap magnet must always be adjusted for maximum picture brightness *only*. With the tube operating and with the brightness control adjusted for low intensity, the

ion-trap magnet is adjusted by moving it forward or back-
ward and at the same time rotating it slightly around the
neck of the picture tube until the raster on the screen is
brightest.

Neck shadow (Fig. 29) can sometimes be corrected by
adjusting the ion trap, however the ion trap should not be
used to correct for neck shadow unless it can be accom-
plished without reducing the brightness. The primary con-
sideration in adjusting the ion trap must be for maximum
brightness or the tube will be permanently damaged.

SUMMARY

The proper placement of a television receiver depends
on many factors as to room layout, size of rooms, lighting
arrangements, power outlets, and antenna lead-in. In choos-
ing a location for the TV receiver, remember to keep direct
sunlight from windows from falling directly on the face
of the screen.

Naturally heat is always a problem, so the cabinet should
never set directly against the wall, and should never set
close to a heat radiator, etc., as the effect of heat will impair
its operation or even damage the receiver.

Every television receiver contains several controls which
are varied to obtain proper picture contrast and sound
transmission. Some adjustments must be varied more often
than others; hence, manufacturers place some controls on
the front, sides, top, or some convenient place on the cab-
inet where they are readily accessible. These controls are
called *operator controls*.

Other controls, called *service adjustments*, are located on
rear panels of the chassis, the chassis itself, or in some
cases on the neck of the picture tube. Most of these controls
are not needed as adjustments during normal reception.
These controls or adjustments generally include, focus, ver-
tical height (size), vertical linearity, horizontal width
(size), horizontal linearity, AGC, and buzz.

REVIEW QUESTIONS

1. What is the difference between operator controls and service adjustments?
2. What adjustments are considered operator controls?
3. What is meant by resolution?
4. What is meant by aspect ratio?
5. What is the purpose of the buzz control?
6. What is the purpose of the ion trap?

Television Antennas and Transmission Lines

All television receivers, irrespective of their location with reference to the transmitting station, require some type of antenna in order to properly function.

Television antennas may be classified according to their location as:

1. Built-in antennas.

2. Indoor antennas.

3. Window antennas.

4. Attic antennas.

5. Outdoor antennas.

6. Master TV antennas (see Fig. 1).

Built-in antennas, as the name implies, are those which are a component part of the television receiver. Many TV receivers are equipped with built-in antennas. Some may be located inside the top of the cabinet, and some may be on the rear-cover of the set. In addition, a built-in tele- scopic antenna is included in many receivers, particularly portables. However, in most locations, it will be found that one of the other types of antennas listed will provide
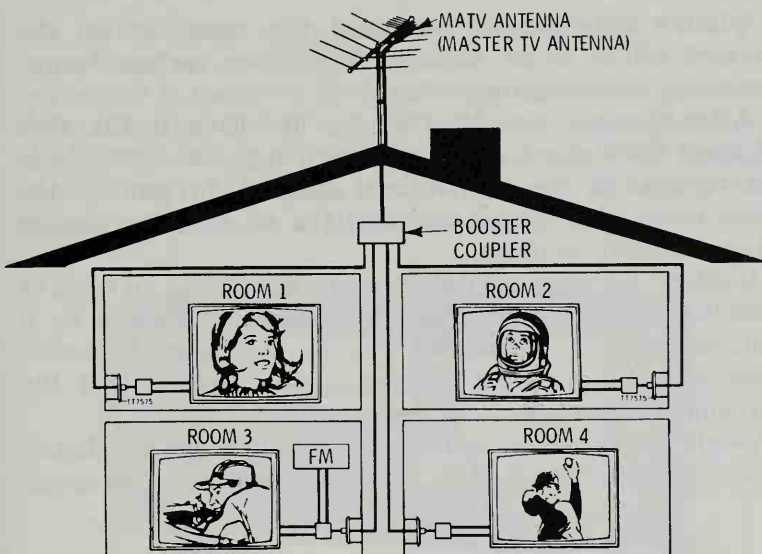
Fig. 1. A small master TV antenna arrangement.

better reception. Built-in antennas are usually connected to antenna terminal screws at the rear of the cabinet. If another antenna is used, the built-in antenna must be disconnected from the terminal screws before the new antenna leads are connected in its place. The most common type of indoor antenna is the familiar "rabbit-ears." Although appearing in several different forms, it, in general, consists of two arms arranged in a "V" shape. Both the length of the arms and the angle of the "V" are usually adjustable.

TV antennas may be classified according to basic design as dipole or Marconi quarter-wave (ground-plane) types. Dipole antennas and their elaborated versions are commonly utilized in fixed installations. On the other hand, the quarter-wave or ground-plane are generally used with portable TV receivers. The latter type of antenna is also called a whip antenna.

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Window antennas are designed for mounting on the window sill or in its vicinity. They take various forms, depending upon requirements.

Attic antennas are designed for mounting in the attic of small dwellings, from which point they are connected to the receiver in the conventional manner. In general, the same types of antennas are used for an attic installation as are used for outdoors.

Outdoor antennas are designed for installation on roofs of dwellings or on towers. They are usually supported by a suitable piece of galvanized iron or aluminum piping or mast whose dimensions depends upon the height of the antenna array.

Community, master, or cable TV installations are distribution systems rather than a specialized type of antenna.
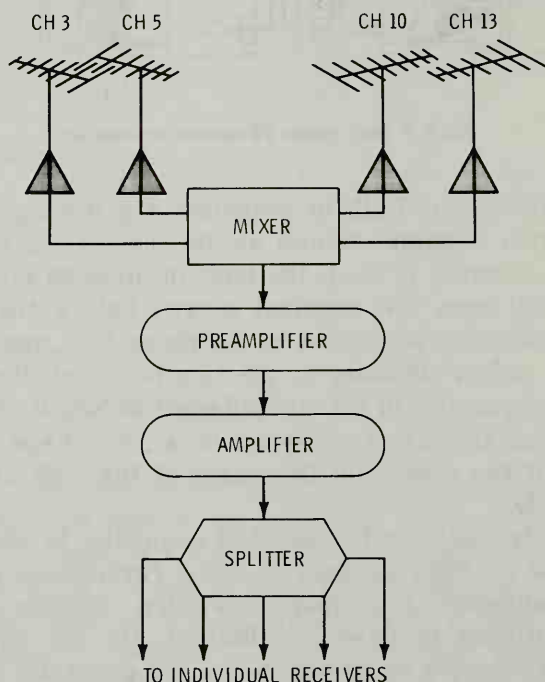
Courtesy JFD

Fig. 2. Typical MATV system for an apartment building.

We will find that quite elaborate antenna arrays are generally used in community systems (see Fig. 2). This requirement is based on the fact that a community system is ordinarily installed in a far-fringe area where the signal level (field strength) is comparatively weak. Field strength is measured in millionths of volts (microvolts) with a field-strength meter such as illustrated in Fig. 3.

Courtesy Jerrold Electronics Corp.

Fig. 3. A precision-type field-strength meter.

The quality of the picture that is reproduced on the screen of a television receiver is dependent upon many factors, some of which are beyond the control of the receiver. The information presented here is intended mainly to assist the service technician in determining the factor the antenna plays in the normal reception of television.

The strength of the transmitted picture signal that reaches the receiver is a vitally important factor in determining the quality of the picture that is reproduced on the screen. A very weak signal will produce an unsatisfactory picture. In locations where the signal is exceedingly weak, the picture will display a milky appearance which is usually accompanied by a speckled effect called *snow*.

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TELEVISION TRANSMISSION

The very-high and ultra-high frequency waves used for the transmission of television picture signals act quite similar to rays of light in that they do not bend around corners and are reflected by obstacles in their path.

Therefore, television waves do not follow the curvature of the earth and reliable reception should only be anticipated in the region determined by the *line of sight¹* to the horizon in all directions from the antenna tower of the transmitting station. (See Fig. 4)
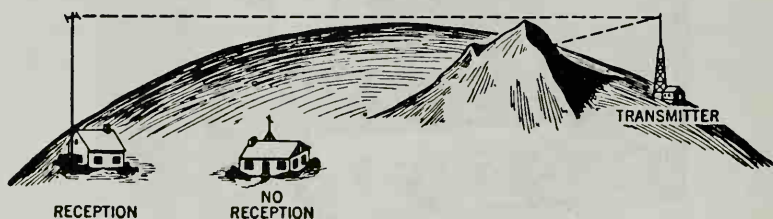

Fig. 4. Line-of-sight transmission.

Since signal strength decreases rapidly when the line of sight distance is exceeded, it is not possible to reliably predict conditions which might prevail at greater distances away from the transmitter. The technician who installs the television receiver must always carefully check to determine if signals at a particular location are of satisfactory strength.

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¹The line of sight distance as denoted in television literature is the maximum distance which high-frequency radio waves will reach without being impeded by the curvature of the earth.

It is illustrated in Fig. 4 and is governed by the relationship:

$$d = 1.41 (\sqrt{h_t} + \sqrt{h_r})$$

Where d is the distance between antennas in miles,
h_t is the transmitting antenna height in feet,
h_r is the receiving antenna height in feet.

The characteristic of high-frequency television signals which permit them to be reflected from the walls of nearby buildings or other objects may, under certain conditions, create "multiple transmission paths." Fig. 5 shows a re-
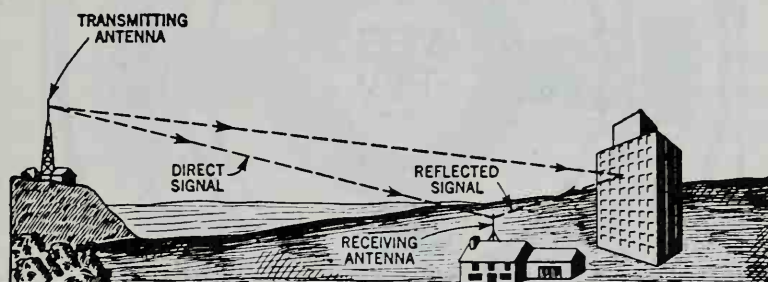

Fig. 5. The direct and reflected signal paths.

flected signal arriving at the receiving antenna a short interval of time later than the signal traveling in a direct path from the transmitter. The effect produced on the picture of the television receiver consists of a multiple image (Fig. 6). These multiple images, known as *echoes* or *ghosts*, can usually be prevented by careful installation and orientation of the antenna.

Do not be mistaken in believing that the reason for the line of sight transmission is due to the television signal. The only reason for the limited transmitting distance is the frequencies used for transmission. If it were possible to transmit television signals at the low frequencies used by broadcast radio, long distances could also be obtained in television transmission. Of course, this is impossible. As pointed out previously, the entire broadcast band comprises a bandwidth only slightly over 1/6 that of a single television channel.

Actually, there is a certain amount of bending of the television waves as they travel along the earth. Very-high frequency (VHF) stations can be received beyond the
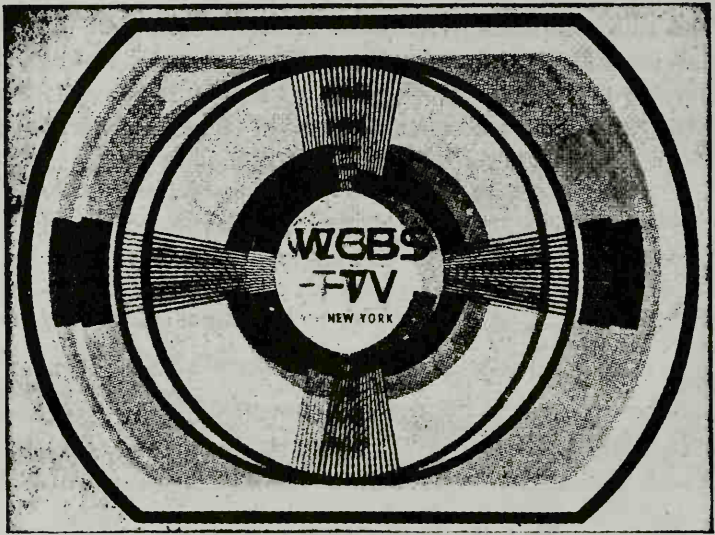
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Fig. 6. Test pattern illustrating a ghost due to reflected waves from intervening or nearby structures.

distance computed to be the horizon. However, at ultra-high frequencies (UHF), the line of sight limitations are more pronounced. Also, at UHF frequencies, reflections and ghosts become more of a problem. In fact, a good signal may be received at one point and just a few feet away no signal will be received because some intervening object has shielded the area. Hence, at UHF frequencies, proper antenna selection and orientation is most important.

The strength of a signal is expressed in microvolts per meter. The field strength is stated as the voltage developed in a wire 1 meter long, at a chosen position in space. If a wire 5 meters long has a voltage of 100 microvolts induced in it by a certain signal, the field strength of the signal is 20 microvolts per meter. Thus, the microvolts-per-meter unit is a measurement of the actual field strength of an electromagnetic wave. On the other hand, a field-strength meter connected to an arbitrary antenna merely measures the microvolts of signal picked up by the antenna. If we

wish to know the field strength of the electromagnetic wave, the antenna that is used must be referenced to a standard 1-meter wire.

TRANSCONTINENTAL TELEVISION TRANSMISSION SYSTEMS

Since television transmission is limited to line of sight, an efficient relay system is necessary to link the country into television networks. There are two principal systems presently used for this purpose. They are:

1. The underground coaxial cable system.

2. The microwave radio relay system.

The coaxial cable system consists principally of a special type of telephone cable capable of passing a wide range of frequencies without the usual prohibitive losses and distortion. For a successful television transmission over longer distance however, in addition to the coaxial cable, special repeater amplifiers (relay stations) are required spaced at equal distances from one another.

The microwave radio relay system of increasing the range of television coverage, on the other hand, consists of a chain of towers located at various distances, depending on the intervening terrain, across the land. Each tower contains a receiver to pick up the signal from the preceding tower and a transmitter to rebroadcast it to the following tower.

This same principle is employed in transcontinental television broadcasts. In the experimental Telstar system, the signal from the transmitting station is beamed toward the satellite as it orbits the earth. This is still line of sight transmission; however, because of the great height of the receiving antenna (on the satellite) the transmitting range is greatly increased.

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At the satellite, the signal received from the ground is amplified and sent to the transmitting antenna where it is retransmitted to a receiving antenna on the other side of the ocean.

Of course, the foregoing discussion has been highly simplified. The signals received are very weak—far too weak for reception by normal receiving equipment. Giant specially constructed antennas are necessary for transmission and reception. Because the satellite is orbiting the earth, its position in respect to a given point is constantly changing. The transmitting and receiving antennas must be able to receive coded messages from the satellite and automatically rotate to keep in step with the satellite's movement. International transmissions from a given satellite are only possible when the satellite is in the line of sight range from both stations at the same time.

The signal is not the same as that transmitted by a television transmitter at present. The frequency used by the ground transmitter (satellite receiving frequency) is 6,390-MHz. The satellite's transmitting frequency (ground station receiving frequency) is 4,170-MHz. In addition since different countries have different transmission standards, the signal received from the satellite must be made to conform to the standards in the country where it is being received.

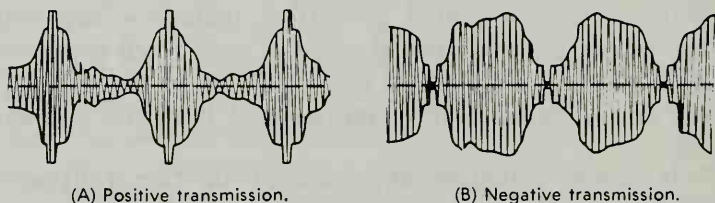(A) Positive transmission.   (B) Negative transmission.

Fig. 7. TV transmission signals.

For example, the United States uses positive transmission of TV signals, as depicted in Fig. 7; on the other hand, England uses negative transmission. Therefore, an English

TV signal must be converted for positive transmission before it can be utilized by U. S. television receivers. Various foreign countries transmit TV signals with more lines in some instances, and with fewer lines in other instances than the U.S. In all cases, the signal received from the satellite must be processed accordingly.

ANTENNA SYSTEM

For best reception, each antenna should be selected with reference to distance and other factors covering the particular installation.

Fundamentally the three elements present in any television antenna installation are:

1. Antenna.

2. Transmission line.

3. Receiver.

The function of the antenna is to pick up the signal transmitted from the station and to transmit the signal to the receiver through the connecting transmission line.
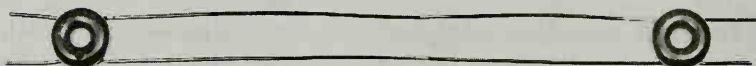
TRANSMISSION LINES

There are four general types of transmission lines acting as a transmission link between the antenna and the receiver. They are:

1. The two-wire, parallel-conductor type.

2. The coaxial cable type.

3. The twisted pair type.

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4. The shielded pair type.

There are several constructional variations in the basic types of transmission lines. In the first type (Fig. 8A), two parallel conductors are supported a fixed distance apart by means of insulators called *spacers*. The air forms the dielectric insulation between the conductors.

(A) Open wire.

(B) Twin lead.
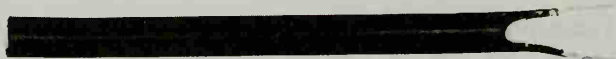
(C) Tubular twin lead.

(D) Coaxial.

Fig. 8. Types of television transmission lines.

The most popular two-wire transmission line is a parallel-conductor line with stranded conductors imbedded in a low-loss insulating material (polyethylene). (See Fig.

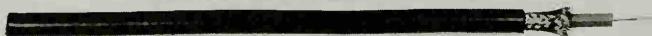8B). It has the advantages of low weight, compactness and neat appearance, together with close and uniform spacing. Losses, however, are higher in the solid dielectric than in air, and dirt or moisture on the line tend to change the characteristic impedance. Two-wire transmission lines of this type are available in impedances of 75, 150, and 300 ohms.

Another type of parallel-conductor twin lead is pictured in Fig. 8C. This type of twin lead is very similar to that of Fig. 8B except that the plastic insulating material is arranged in a tubular fashion and the inside is filled with a low-loss foam material. Tubular lead exhibits less loss than ordinary flat twin lead; hence, it is widely used in UHF applications.

The most common type of coaxial transmission line consists of either a solid or stranded wire inner conductor surrounded by polyethylene dielectric. Copper braid is woven over the dielectric to form the outer conductor, and a waterproof vinyl covering is placed on top of the braid as shown in Fig. 8D. This cable is made in a number of different diameters. It is moderately flexible and so is easy to install. Coaxial cable is available in characteristic impedances of 52, 72, or 150 ohms.

Air-insulated, coaxial-cable transmission lines are also available. They have lower losses than the solid dielectric type of Fig. 8D, but are less used because they are expensive and difficult to install as compared with the flexible type. A common type of air-insulated coxial cable uses a solid-wire conductor inside a copper tube, with the insulating "beads" spaced at regular intervals.

Most television receivers are manufactured with an input impedance of 300 ohms. Thus, if a coaxial transmission line is used, some means must be provided to match the lower impedance of the transmission line (usually 72-ohms) to the 300-ohm impedance of the receiver. A special device, called an *impedance-matching transformer* is employed between the transmission line and the receiver antenna terminals.

Another example of an impedance-matching arrangement is found in the connection of two television receivers to the same 300-ohms lines. In this case, a *splitter* is generally used, both to provide correct impedance matching and to isolate the two receivers from each other. In other words, unless a suitable degree of isolation is provided, the radiation from one receiver could produce interference in the picture displayed by the other receiver. Two basic splitter configurations are shown in Fig. 9. The resistive splitter has the disadvantage that it imposes a signal loss. This loss is often tolerable when the incoming signal is strong. When less loss is desirable, the inductive type of signal splitter is used.
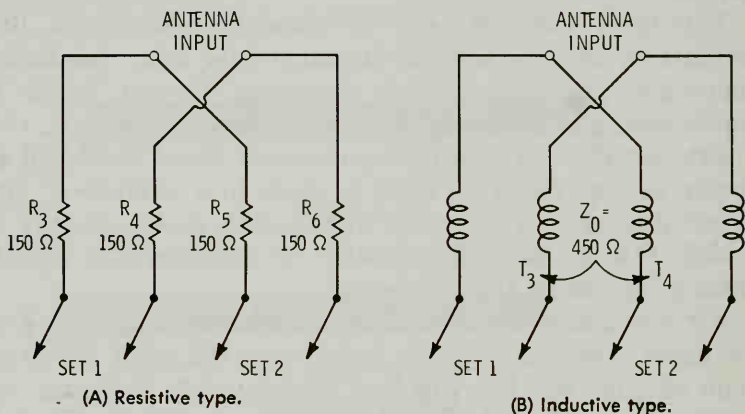
Fig. 9. Basic signal-splitter configurations.

PRACTICAL ANTENNA CALCULATIONS

For proper antenna design it is necessary to know the length of the electromagnetic waves involved. In order to determine wavelengths, however, it is necessary to know the speed at which electromagnetic waves travel through free space and the frequency. In speaking of the frequency of electromagnetic waves we merely mean the number of waves passing a given point in one second, expressed in megahertz (millions of hertz).

Since electromagnetic waves of all lengths move at the same speed, the number of waves passing a given point in one second will be small if the waves are long, and large if the waves are short. Thus, 500,000 waves 600 meters in length will pass a given point in one second at a frequency of 500,000 Hertz. Similarly, if the waves were only one meter in length 300,000,000 would pass each second at a frequency of 300 MHz.

The actual velocity of electromagnetic waves is for all practical purposes 300,000,000 meters or 984,300,000 feet per second.

Now, if the speed at which the waves travel is equal to 3×10^5 meters per second, the distance it will cover in one cycle will be equal to this velocity divided by the frequency in hertz per second, or:

$$\lambda = \frac{3 \times 10^5}{f}$$

where,

λ (the Greek letter Lambda) is the wavelength in meters, and f is the frequency in hertz per second.

Since feet and inches are the measurements most commonly used in the U.S. the foregoing formula can be converted to:

$$\lambda = \frac{984}{f}$$

where,

λ is the wavelength in feet,
f is the frequency in megahertz.
and:

$$\lambda = \frac{11,808}{f}$$

where,

λ is the wavelength in inches,
f is the frequency in megahertz.

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The values obtained in the foregoing equations are only approximate; however, they are accurate enough for all practical applications.

The length of a dipole antenna is one-half wavelength. Each dipole antenna consists of two elements each one-quarter of a wavelength long as shown in Fig. 10. Thus:

$$\frac{\lambda}{4} = \frac{2,952}{f}$$

where,

$\lambda/4$ is the length of a quarter-wavelength in inches, and f is the frequency in megahertz.

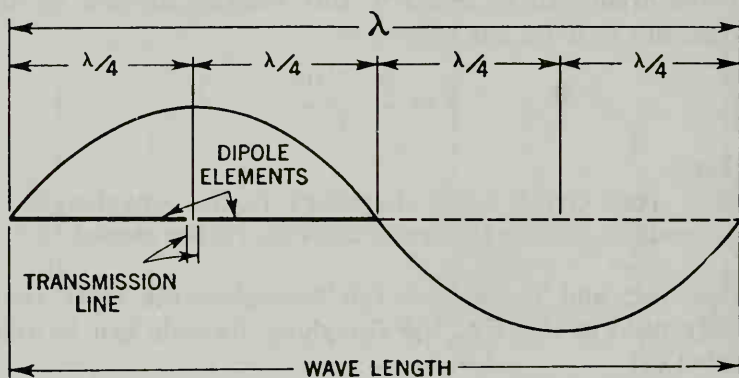Fig. 10. Relationship between wavelength of received signal and length of dipole element.

Due to the electrical characteristics of the antenna material, it has been found that the antenna elements should be somewhat shorter (about 5 percent) than that given in the foregoing formula. The formula then becomes:

$$\lambda/4 = \frac{2,952 \times 0.95}{f}$$

$$= \frac{2,804 \text{ inches}}{f}$$

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From this latter formula it is comparatively simple to obtain the antenna dimensions for each frequency, by substituting the proper value in megahertz (MHz).

Dipole antennas that are to be used in outside installations usually consist of two quarter-wavelength sections of 3/8 in. aluminum tubing or rod.

The following example shows the general procedure when it is desired to calculate the exact length in inches of each element (quarter-wavelength) of a simple half-wave dipole antenna.

Example.—It is desired to determine the length of a quarter-wave dipole rod suitable for use on channel four, where the frequency has an average value of 69 MHz. What is the dipole rod length?

Solution—By employing the foregoing formula, a substitution of values gives the quarter wavelength in inches:

$$\lambda/4 = \frac{2,804}{69}$$

$$= 40 \text{ (Approx.)}$$

By using a similar procedure, it is a comparatively simple matter to calculate antenna dimensions for any desired channel or frequency.

DIPOLE ANTENNAS

The fundamental form of a dipole antenna consists of two single wires, rods, or tubes, whose combined lengths are approximately equal to half the transmitting wavelength. It is from this basic unit that various forms of television antennas are constructed. It is also variously known as a *half--wave dipole, half-wave doublet* or *Hertz* antenna.

The dipole elements are made of steel, aluminum, or copper alloy tubing and are surface treated against corrosion. The receiver dipole is equipped with terminals at its adjacent ends for transmission-line connections and must be properly insulated from the mast or supporting struc-

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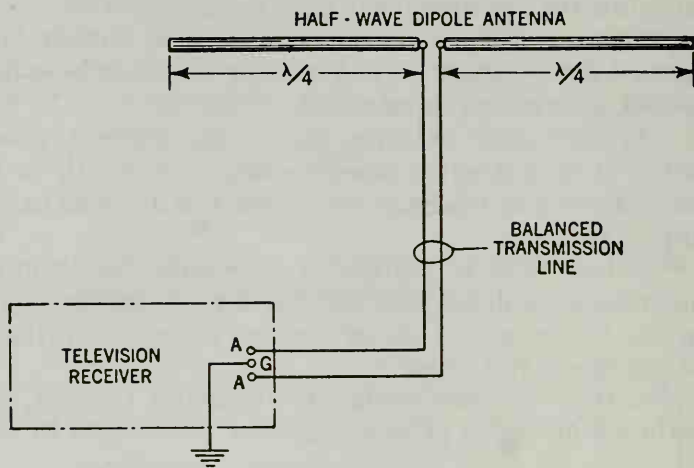ture. The dipole element is then connected to the receiver via the transmission line as shown in Fig. 11.

Fig. 11. Transmission line connection between half-wave dipole and receiver.

Actually the simple dipole antenna (Fig. 12) is seldom used in modern television systems. However, it is the basis for practically all television antennas. Therefore, it has been included in our discussion of antennas.

Folded Dipoles—The necessity for separating, insulating, and mounting the receiver dipole at its center tends to
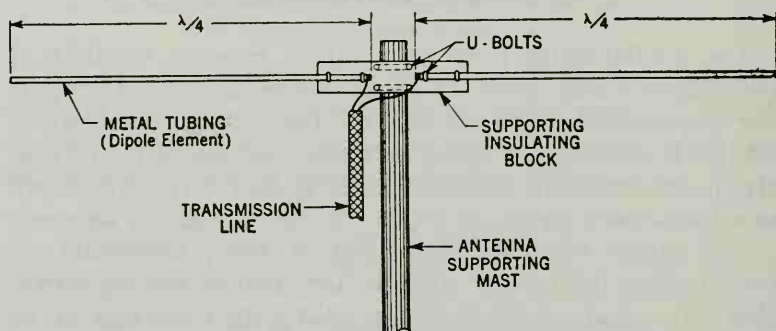

Fig. 12. Mounting arrangement and connection of half-wave dipole antenna and transmission line.

weaken and complicate the antenna assembly. Because of this, a considerable simplification may be obtained by employing an unbroken member bent as shown in Fig. 13. A television antenna of this type is known as the folded-dipole type and is widely used.

The spacing between the folded dipole elements should vary inversely with the frequency, that is, the higher the
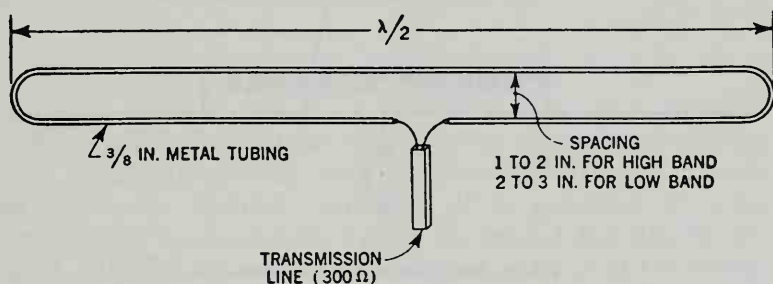

Fig. 13. Dimensions of a folded-dipole antenna.

frequency the smaller the spacing. The element spacing for the center frequency on the low band is usually 2 to 3 inches, and 1 to 2 inches for the high band.

T-Matched Dipoles—A further combination of the common half-wave dipole and the folded dipole has become known as the *T-matched* dipole. Two types of T-matched dipoles are shown in Fig. 14. The assembly is obtained by cutting the ends of a folded dipole and fitting the remaining stub ends to the bottom element, the T-section having a length of two-thirds the length of the dipole. Both of the arrangement in Fig. 14 have identical electrical characteristics. The spacing between the T-section and the dipole is the same as for the folded dipole.

One of the first requirements for television reception is that the antenna system should be flatly tuned; that is, it should respond fairly evenly over the waveband involved and also pick up the FM sound transmissions. This compromise is often assisted by choosing the length of the antenna
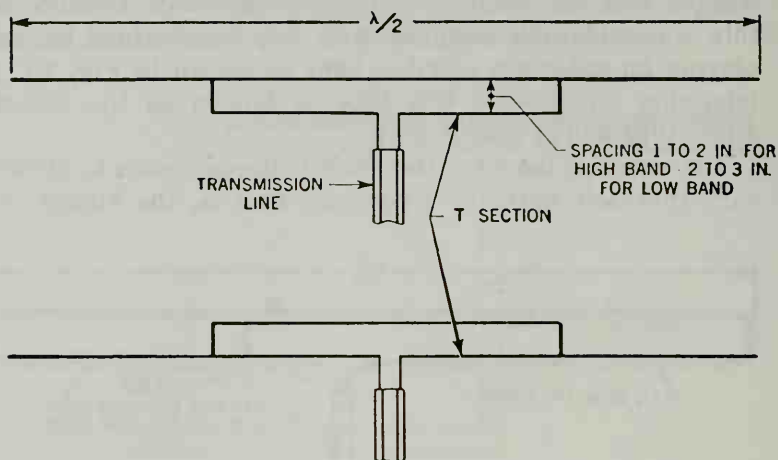
Fig. 14. Two types of T-matched antennas.

to resonate at a frequency intermediate between sound and video transmission.

The polarization of the signal waves to be received may be either vertical or horizontal. An antenna placed in the horizontal plane radiates horizontally polarized signals, whereas, an antenna placed in a vertical plane radiates vertically polarized signals.

To obtain maximum energy transfer, the receiving antenna should be polarized in the same manner as the transmitting antenna. In the U.S., horizontal polarization is used at the transmitter; hence it should also be employed
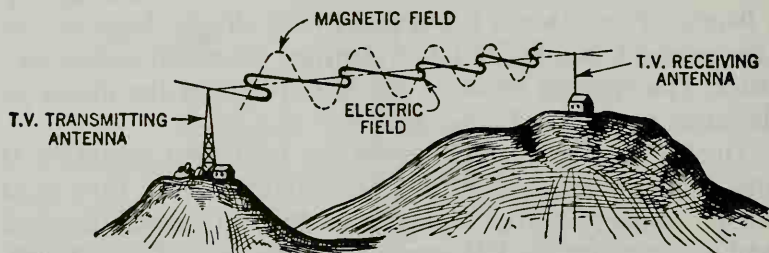

Fig. 15. Magnetic and electric fields of horizontally-polarized signal waves.

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at the receiver. Horizontal polarization means that the dipole element should be placed in the horizontal plane, that is, parallel with the ground as shown in Fig. 15.

In England, vertical polarization is employed; hence the dipole should be placed perpendicular to the ground or standing on end by American standards. Either method will work. The important factor is that both transmitting and receiving antennas should be placed the same.

PARASITIC ELEMENTS

A parasitic element, as employed in television antennas, is a dipole slightly too long or too short for exact resonance at the desired frequency. It is mounted at some fraction of a wavelength before or behind the driven element (dipole). Parasitic elements are not cut at the center and are not connected to the transmission line. The center point of a parasitic element is electrically neutral and can be grounded. This is convenient for lightning protection, as it permits making the entire antenna structure of conductive tubing such as aluminum and grounding the central supporting mast at the base.

Current induced in a parasitic element by the advancing wave front produces a local field about it which is coupled to the driven element because of the physical closeness. Spacing and tuning of parasitic elements are adjusted so that the currents produced in them by the received signal produce fields which add in correct phase to reinforce the field of the received signal at the driven element. For signals from the opposite direction, the action is exactly reversed, and the signal is substantially cancelled in the driven element.

Director and Reflector Elements—A direct element is about 4 percent shorter than the driven element for average element spacing, and is mounted in front of the driven element on the horizontal support member which holds all the elements in proper relationship. The spacing between the director and the driven element can vary from

about 0.08 to about 0.15 wavelength in practical antennas. Closer spacing will increase the front-to-back ratio but makes the array tune more sharply, which is a disadvantage when many widely separated television channels must be received on a single antenna. Wider spacing helps broaden the tuning of the array, but lowers the front-to-back ratio.

A reflector element is about 5 percent longer than the driven element at usual spacings and is mounted on the supporting bar behind the driven element, as shown in Fig. 16. While the spacing between the elements is shown as 0.25 wavelength in Fig. 16, it will vary from about 0.10 to 0.25 wavelength in an actual antenna. The effects of changing the spacing are quite similar to those produced by similar changes in the director length.

The effect of the reflector is critically dependent upon the spacing between reflector and dipole. When the spacing is one-quarter wavelength, radiation from the reflector will exactly reinforce that from the dipole in a forward direction.

The explanation of this effect is easiest explained when the dipole is considered as a transmitting antenna. It is as follows: Radiation from the dipole travels both forward and backward. In the latter direction it reaches the reflector and induces a current in it. Since the radiation has traveled a quarter wavelength on its way to the reflector, it will be 90 degrees lagging in phase relation to that from the dipole where it originated. A current of this phase lag is therefore set up in the reflector, which in turn reradiates the signal.

By the time this secondary radiation has returned to the dipole it is an additional 90 degrees late in phase, making a total phase lag of 180 degrees. However, the oscillations in the dipole will have progressed through a half-cycle during this half-wave time interval, and will be 180 degrees ahead of the initial condition, when the radiation left on its way to the reflector. That is to say, the radiation from the dipole will be a half-cycle ahead of the reference point,
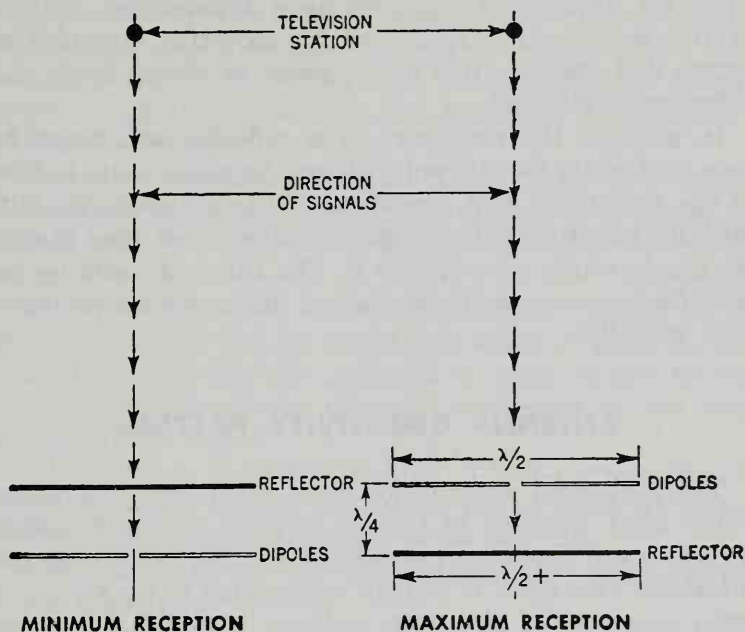
Fig. 16. Location and effect of the reflector element on signal reception.

while that returning from the reflector will be a half-cycle late, bringing the two to the same point in the period of an oscillation.

Being in identical phase, the radiations from the dipole and reflector reinforce each other in the forward direction. The reverse is true for signals from the backward direction; that is, from the direction of the reflector. Here, the two signals cancel.

If the current induced into a reflector was as great as that flowing in the dipole, each would produce the same radiated field strength. The forward radiation would therefore be doubled, while that to the rear would be exactly cancelled, giving zero backward radiation.

Since the problem of radiation and absorption (transmission and reception) by an antenna system are strictly reversible in all ordinary conditions, these directional effects,

when the antenna is regarded as a transmitter, will be exactly similar when it is used for reception, provided of course that waves arrive in the plane in which dipole and reflector are situated.

In practice the resistance of a reflector will never be zero, and while the current in it can be made equal to that of the radiator if both are connected to a feeder, the current in a parasitic reflector must always be less than that in the dipole which gave rise to it. The forward radiation is, therefore, never exactly doubled or the backward radiation fully cancelled.

ANTENNA DIRECTIVITY PATTERN

The horizontal antenna dipole is inherently directional, being most effective to signals arriving in the broadside direction and least effective to those arriving from a parallel direction. This effect is usually represented in the form of a polar diagram, or directivity pattern, in which the radius of the curve from the center of the antenna elements represents the relative response in any given direction.

The function of an antenna pattern is primarily to enable the service technician to evaluate the efficiency of an antenna and assist in the proper orientation on the site of installation.

Plotting an antenna pattern is generally accomplished as follows: A minimum usable value of signal strength is chosen on the basis of what the average television receiver will require for satisfactory reception. Then all the points in the area surrounding the antenna where exactly this value of field strength is found are plotted by bearing from true North or some other convenient reference direction, and distance in miles, or some other desired linear unit. With a sufficient number of points plotted, a continuous smoothly curving line is drawn joining them all, and it will be reasonably certain that all the area enclosed by this curve will provide at least the minimum required signal.

In practical service work, directivity patterns are always plotted in terms of voltage gain, as this unit is most convenient to use in connection with the field-strength meter. which is usually a part of the television service technicians equipment.

Antenna receiving patterns are usually made by rotating the antenna about its vertical axis and plotting values of voltage gain radially outward from the center of each change of angle.

The complexity of an antenna has a direct bearing on its efficiency as well as its directional effects. Roughly, the voltage developed in the antenna is proportional to the combined lengths of the elements multiplied by the field strength of the signal.

This length is measured in units of half-wavelengths. A reduction in the voltage realized at the antenna terminals results from the mutual coupling of the elements.

A comparison of the theoretical efficiency of various types of antennas are as follows:

Elements	Type	Voltage gain
1	Simple Dipole	1.0 (reference)
2	Dipole and Reflector	1.6
4	2-Bays	2.3
6	3-Bays	2.8
8	4-Bays	3.2

In the foregoing, the reference value of 1.0 shown for a simple dipole is the universal standard of comparison. This reference dipole is cut to a half-wavelength for each channel measured.

As previously noted, the voltage developed by a half-wavelength antenna is proportional to the length of the antenna. Therefore for purposes of adding additional elements, multiples of half-wavelengths are used.

The receiving antenna height particularly in fringe areas, is an important factor in its efficiency, or signal capture, as shown in Fig. 17. The possibility of interference is shown
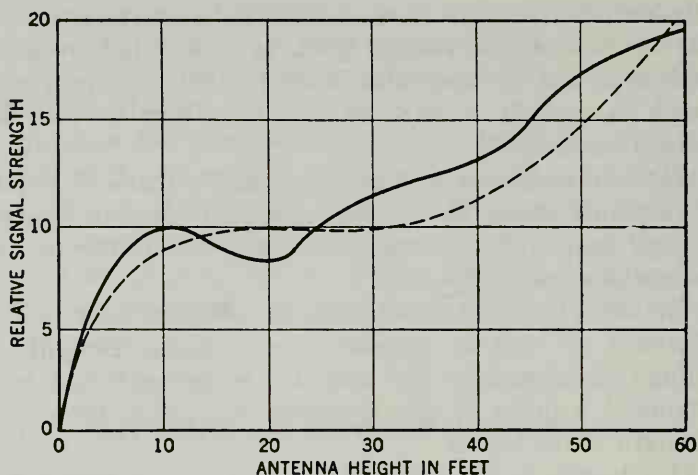
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Fig. 17. Relative signal strength at antenna per height in feet (applies only at considerable distance from transmitter).

by the irregularity of the curve representing signals in the high-channel group. This particular effect, however, is not predictable and can only be determined by proper orientation.

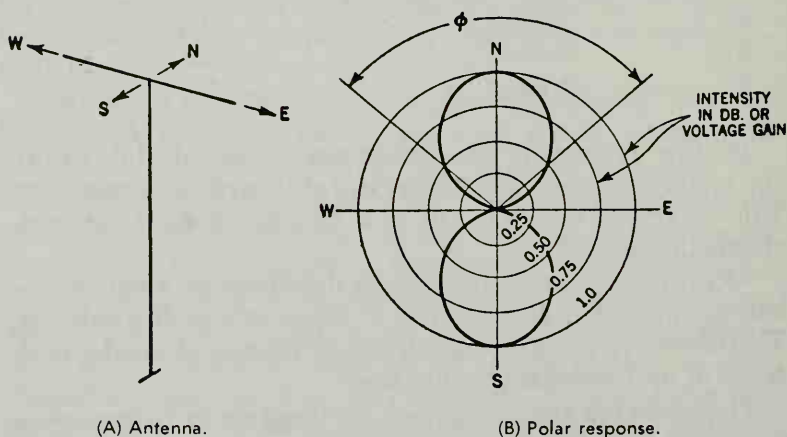(A) Antenna.   (B) Polar response.

Fig. 18. Directional response pattern of a dipole antenna.

The field pattern (directional-response pattern of a typical dipole antenna is shown in Fig. 18.

For the sake of simplicity, the directions are given as North, South, East, and West in both the schematic antenna and the polar diagram. From this diagram, it will readily be observed that the maximum signal strength will be obtained when the antenna is broadside to the transmitter. Similarly the "signal capture" is not critical over the angle Φ, which includes the rotation over which the antenna can be rotated before losing more than half of its effectiveness. In the diagram the concentric circles represent the voltage gain, where unity, or 1.0, is taken as reference for all comparisons.

If a reflector is added to the dipole, the gain and directional characteristics of the antenna are changed and the polar diagram will take the form indicated in Fig. 19. It will
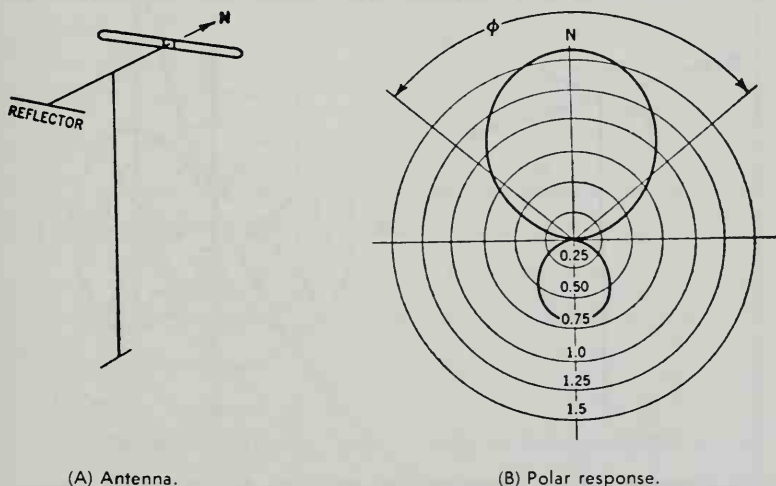

(A) Antenna.   (B) Polar response.

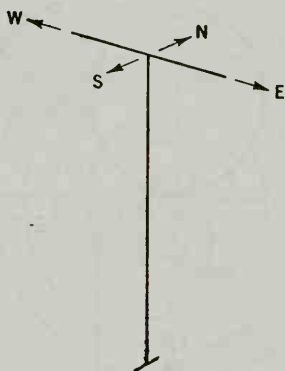**Fig. 19. Directional response pattern of a folded-dipole antenna with reflector.**

be observed from the diagram that the angle Φ, is still sufficiently wide, generally at least 80 degrees.

So far, an antenna operating only on the channel for which it was designed has been considered. It is the usual

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practice to use dimensions which give half-wave dipoles in the middle of the low channels. When used on the high channels, a third harmonic will result, giving an antenna pattern shown in Fig. 20.

A dipole operated in this way will have six lobes, and unless certain dimensions are revised, these lobes are symmetrical and oriented as indicated. With reference to the field pattern, these lobes are too narrow and are pointing in different directons from that previously shown. This will make orientation difficult or even impossible if the stations on the high and low band channels are in the same direction. From this it follows, that no reliable antenna manufacturer would sell an antenna with these characteristics without showing the relation of the lobes for each frequency.

The ratio between maximum and minimum voltage (measured with a voltmeter slid along the transmission
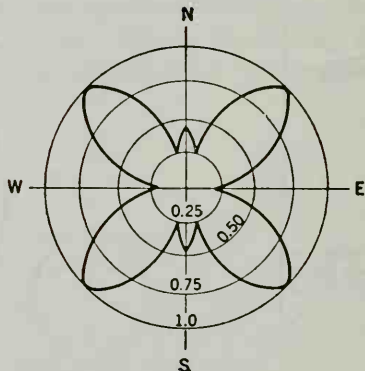
(A) Antenna.   (B) Polar response.

Fig. 20. Directional response pattern at a frequency other than the one the antenna is cut for.

line) is called the voltage standing-wave ratio, abbreviated VSWR. It is obtained numerically by dividing the maximum by the minimum voltage. Thus maximum and minimum values of 15 and 5 would mean a SWR of 3.

If the SWR is plotted on a logarithmic scale against per-cent loss, the curve will take the form shown in Fig. 21. Here it will be observed that a SWR of two will cause a loss of only 10 percent, while a SWR of three will cause a loss of 25 percent.

ANTENNA IMPEDANCE MATCHING

Impedance matching is a very important factor in antenna installations. When the receiver input matches the impedance of the transmission line, the transmitted signal is completely absorbed and as a result there are no reflections or standing waves on the transmission line, and
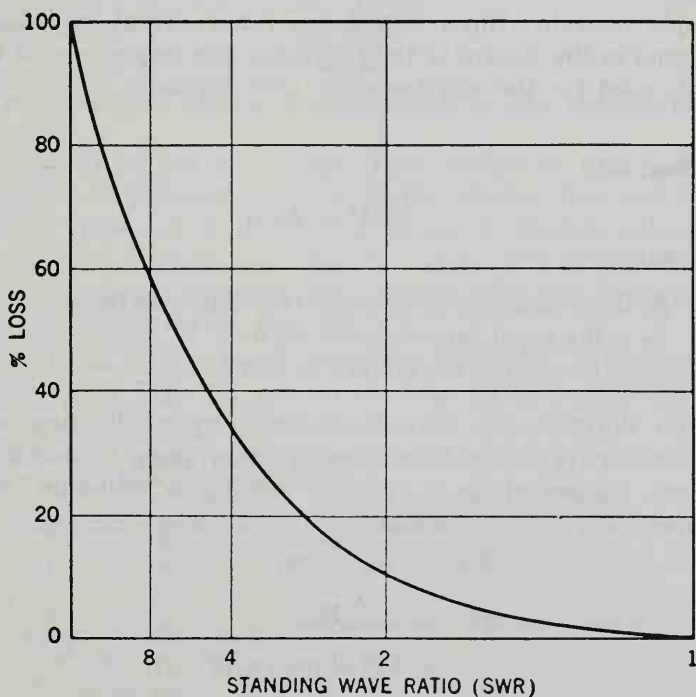

Fig. 21. Relationship between voltage standing-wave ratio and percent of loss due to mismatch.

consequently no ghost images. It should be observed that the antenna impedance is important only from the standpoint of power transfer. It is only when the antenna impedance matches that of the transmission line that maximum power transfer takes place.

A condition which may easily arise is the mismatch of 300 ohms to 72 ohms; this produces a SWR of four and a loss of 37 percent. This condition will result when a 72-ohm antenna is connected to a receiver having a 300-ohm input impedance. Mismatch, and consequent loss of gain, also occurs when the antenna and receiver are not connected by transmission cable of proper characteristic impedance.

Impedance matching is most commonly accomplished by the use of the impedance inversion characteristic of a one-quarter wavelength section of cable. This is expressed by the simple relation: Input impedance times output impedance is equal to the square of the characteristic impedance of the cable used for the quarter-wave transformer.

That is:

$$(Z_0)^2 = Z_S Z_R$$

where

Z_0 is the characteristic cable impedance in ohms.
Z_S is the input impedance in ohms.
Z_R is the output impedance in ohms.

To illustrate an impedance-matching application of a quarter-wave linear transformer, when using a 72-ohm antenna connected to a receiver having a 300-ohm input impedance, we can calculate:

$$(Z_0)^2 = 72 \times 300,$$
$$Z_0 = \sqrt{21,600}$$
$$= 147 \text{ ohms (approx.)}.$$

From our calculation it will be observed that a quarter-wave section from a 150-ohm twin conductor line will be
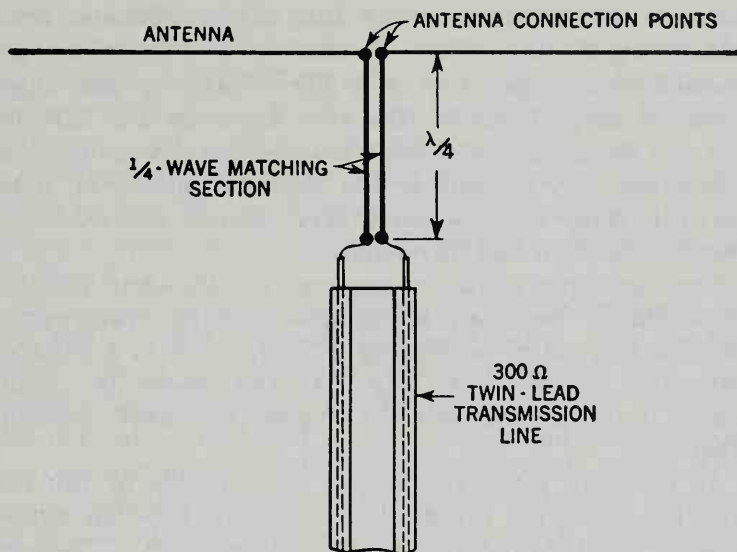
Fig. 22. Insertion of a quarter-wave matching section to obtain impedance match.

very close to a perfect match. This section of line should be spliced in between the end of the 72-ohm line and the receiver input. If it is desired to use a 72-ohm antenna and 300-ohm transmission line, the same matching section can be connected between the antenna and the transmission line as shown in Fig. 22.

Two other methods of matching different impedances are shown in Figs. 23 and 24. In Fig. 23, it is desired to
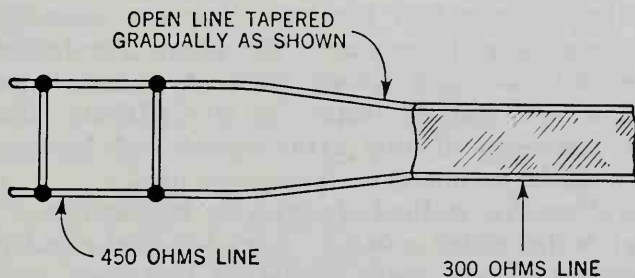

Fig. 23. Proper way of connecting a 450-ohm line to a 300-ohm line.

match a 450-ohm, open-wire line to the 300-ohm input impedance of the receiver. A quarter-wave line, having a characteristic impedance of $\sqrt{300 \times 450}$ or 368 ohms, could be used; however, the two wires on the 450-ohm line can be tapered and bent inwards as shown until the impedance they present is 300 ohms. It should be noted that this taper must be made very gradual and extending over a distance of two wavelengths.

The two quarter-wave sections of 150-ohm line are connected to form an impedance-matching transformer. Another method of connecting a 75-ohm line to a 300-ohm impedance is shown in Fig. 24. The length is usually chosen to be one-quarter wave long at the lowest operating frequency.

As noted in the diagram the 75-ohm ends of the two lines are connected in parallel. Thus, two 150-ohm impedances in parallel produce a resultant impedance of 75-ohms.
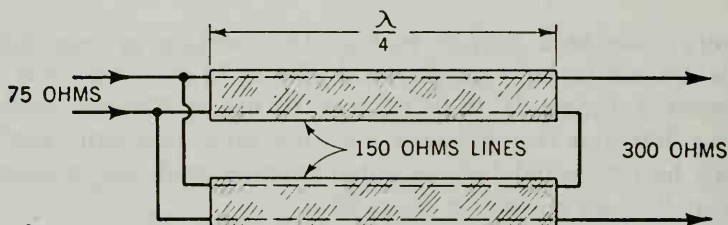

Fig. 24. An impedance-matching transformer using transmission lines.

At the other end of the lines they are connected in series, producing the necessary 300 ohms. The impedance at one end can be balanced while it is unbalanced at the other end and the match is still effective. Because of the simplicity of this arrangement and the ease at which it can be produced, it is commonly used.

In still another method of matching impedances, a commercial device called a *balun* (from *bal*anced-*un*balanced) is employed. These units consist of two coils, each of which can be considered as a transmission line having a

surge impedance of 150 ohms and a length of approximately one-quarter wave at the lowest operating frequency. The two transmission lines, or coils, are connected in parallel on one end, forming the 75-ohm impedance and in series on the other end, producing the 300-ohm impedance.
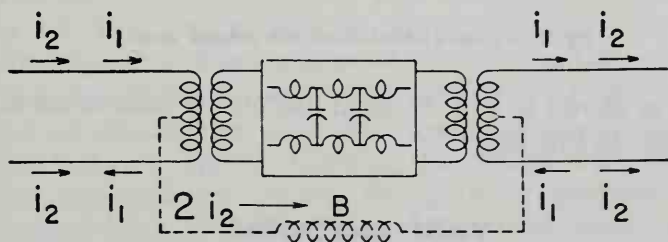
The transmission-line coil and equivalent diagram are shown in Fig. 25. As illustrated, the transmission line T, having a surge impedance of 150 ohms, is wound on the coil form F.

The magnetic fields produced by the symmetrical or push-pull current i_1 neutralize each other, due to the closely spaced conductors of the transmission line. The magnetic fields produced by the unsymmetrical or push-push current i_2 are added together and would pass through the transmission line if it were not wrapped to form a coil.

The mutual inductance between the individual turns of the coil acts like a conventional choke coil B which offers a high impedance to the push-push currents. The trans-
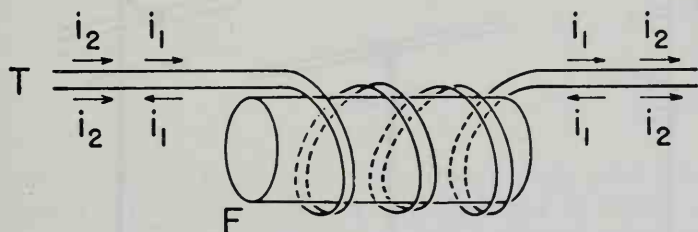
(A) Transmission lines.

(B) Equivalent diagram.

Fig. 25. Transmission-line coil and equivalent diagram for a balun.

mission line coil therefore acts as an ideal transformer which passes the push-pull currents and eliminates the push-push currents.

STACKED ARRAYS

It has been found that additional antenna gain may be obtained by stacking the conventional dipole and reflector. This consists in arranging one driven element on top of another at a spacing that will cause the signals to be in phase at the terminals where the transmission line is connected to the antenna system. (See Fig. 26).

The stacked dipole and reflector can be made broadband so that one unit will operate over all the low-band channels and the other set of elements will operate on the high-band channels. For this reason, this type is made with two sets of elements, either above each other on the

Fig. 26. A stacked folded-dipole with reflector array.

mast, as shown in Fig. 27 or in line on the same cross arm as shown in Fig. 28.

YAGI ANTENNAS

Generally, there is no benefit gained by adding additional reflectors. However, additional directors can be
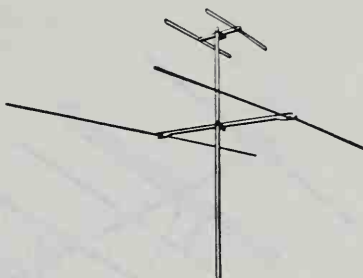
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Fig. 27. A high- and low-band combination antenna.

Fig. 28. A double folded-dipole antenna (inline) with reflector.

added. When more than one director is used with the folded dipole and reflector, the antenna is called a Yagi (named after Hidetsugu Yagi, the Japanese physicist who discovered it). Two types of Yagi antennas are shown in Fig. 29. This type of antenna provides a very high gain.

The principle disadvantage of the Yagi antenna is that it is highly directive (see Fig. 30) and covers a very narrow band of frequencies. Both of these factors and its high gain make it highly desirable for fringe-area use. As more directors are added, the gain is increased; but the bandwidth is narrowed and the directivity pattern becomes sharper. For VHF applications, Yagi antennas with up to 10 elements are employed; for UHF even more elements may be used.
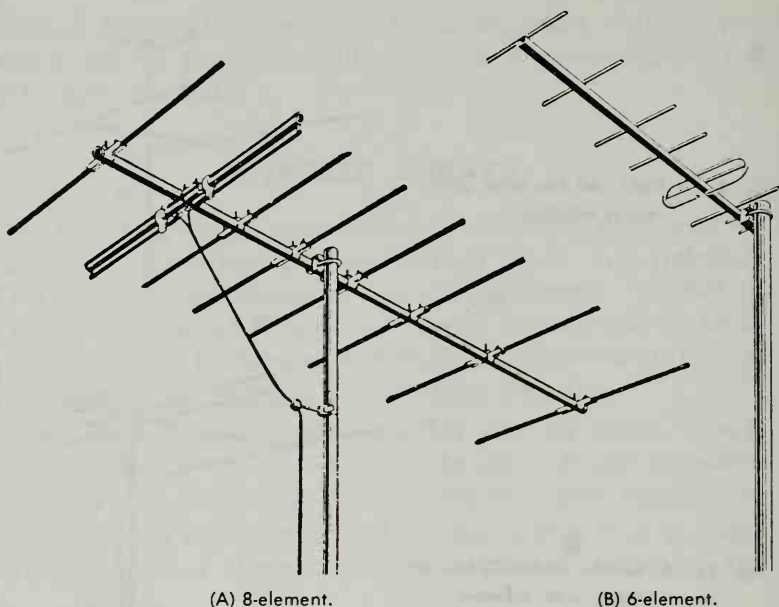
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(A) 8-element.   (B) 6-element.

Fig. 29. Two commercial Yagi antennas.

Optimum operation at VHF frequencies can only be obtained for 1 channel with a Yagi antenna; however, satisfactory operation may be obtained for 2, 3, or even more adjacent channels. For UHF operation several adjacent channels can usually be received from a single Yagi antenna. For even greater gain, two Yagi antennas can be stacked one above the other.

CONICAL ANTENNAS

As the size of the dipole antenna elements is increased, the band of frequencies which the antenna will respond to is increased. The conical antenna makes use of this principle. The original version of the antenna is pictured in Fig. 31. Actually, better performance would be obtained if solid copper cones were used. However, this arrangement
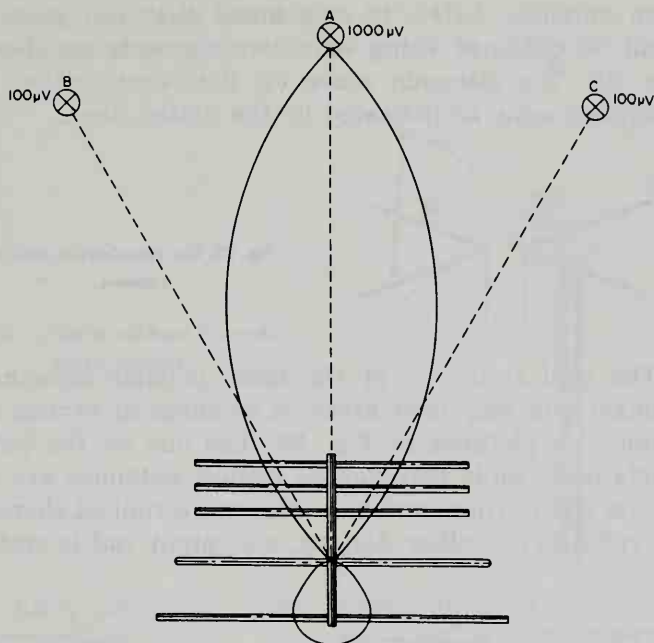
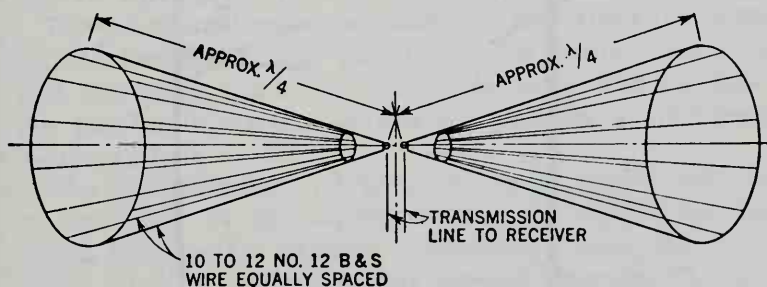Fig. 30. Response pattern of a Yagi antenna to signal from 3 different angles.

Fig. 31. Construction details of the original conical antenna.

is impractical because of the weight, especially in locations where high winds, sleet, and snow are encountered. Thus, wire rods arranged in a conical shape were employed. For obvious reasons, this antenna was called a

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cage antenna. Later, it was found that the same effect could be obtained using only two elements as shown in Fig. 32. The elements make up the cross section of an imaginary cone as indicated by the dotted lines.
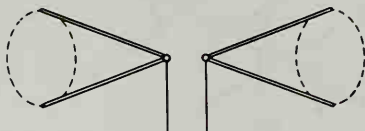
Fig. 32. The two-element conical antenna.

The conical is one of the most popular antennas for primary and secondary areas. A commercial version of the antenna is pictured in Fig. 33. The one on the left is a single unit, while two stacked conical antennas are shown on the right. These antennas also use a conical element for the reflector; in other designs, a straight rod is employed.
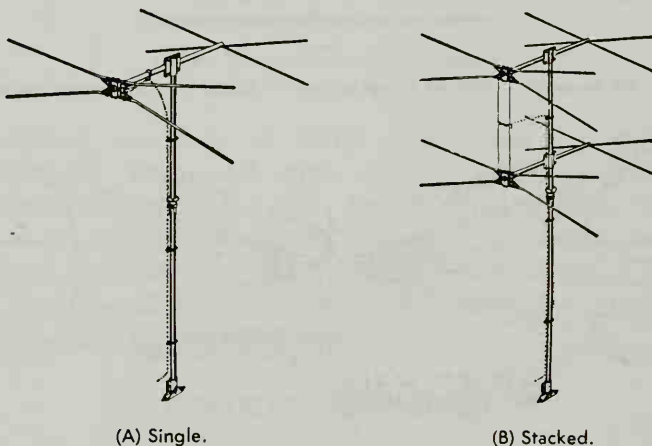
(A) Single.   (B) Stacked.

Fig. 33. Two types of conical antennas.

TRIANGULAR DIPOLES

A triangular dipole antenna is shown in Fig. 34. It is probably the simplest and least expensive broad-band

receiving antenna in the 470-to 890-MHz UHF frequency range. The unit is constructed in the form of two triangles

Fig. 34. A UHF broad-band triangular dipole antenna.

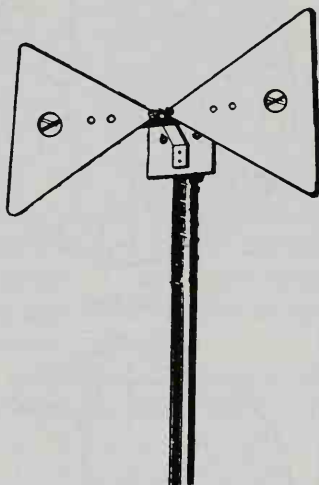from hard aluminum sheet, supported by a suitable insulator, although other materials such as wire screen or metal rods can be used, provided that the conductor spacings are small in comparison to one wavelength.

The directional response pattern of the triangular dipole retains the figure-eight pattern of the straight dipole at both the upper and lower ends of the band. Fig. 35, shows the familiar horizontal directivity patterns at 100-megahertz intervals.

The impedance of a triangular dipole varies with the corner angle of the dipole section. To obtain the best match for 300-ohm balanced transmission lines, the corner angle should be approximately seventy degrees. The total antenna length for greatest overall gain is sixteen inches as shown in Fig. 36.

To provide increased gain and directivity from the triangular dipole, several units may be stacked as shown in Fig. 37.

When employing a single triangular dipole, the 300-ohm transmission line is attached directly to the neighbor-

(A) 500 MHz.

(B) 600 MHz.

— HORIZONTAL   VERTICAL----

(C) 700 MHz.

(D) 800 MHz.

(E) 900 MHz.
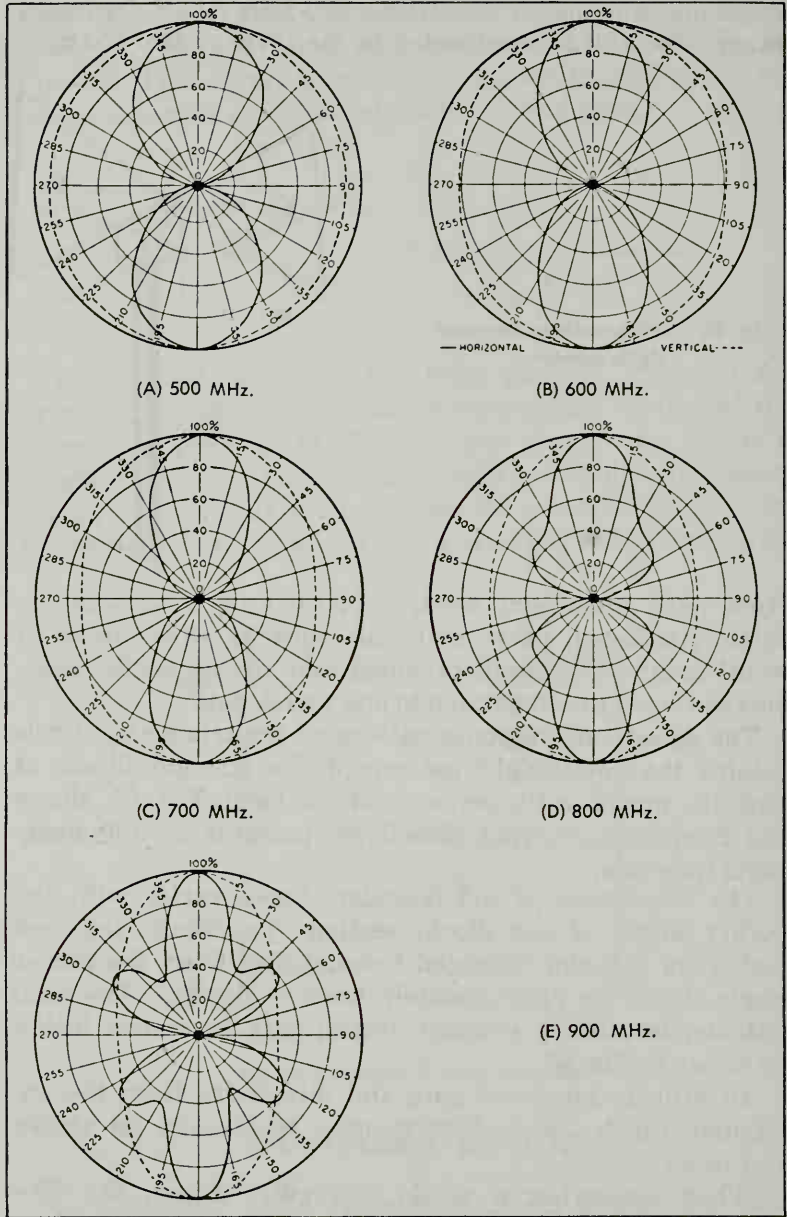
Fig. 32. Directivity patterns of a triangular dipole antenna.

Fig. 36. Triangular dipole antenna connections.
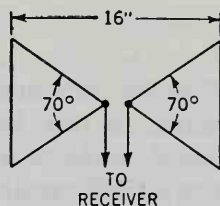
ing ends of the triangular sheets. For the two-stacked array, two small rods connect similar ends together, and the 300-ohm line would be connected to the center points of these rods. When a four-bay array is used, the connections shown in Fig. 37B give the best results. The crossovers are necessary to obtain the correct phasing.

It should be observed that the matching arrangements used with UHF antennas are the same as those used for the VHF types.
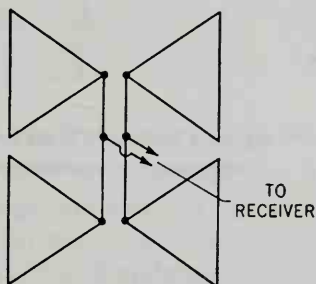
(A) 2 units.
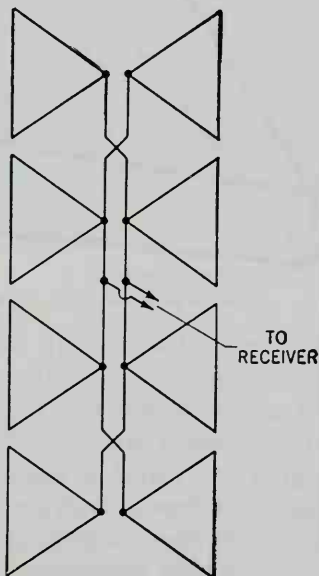
(B) 4 units.

Fig. 37. Methods of connecting stacked, triangular, dipole arrays.

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"V" ANTENNAS

The "V" antennas is another version of the basic dipole antenna. In this antenna, the dipole elements are slanted forward to form a "V" shape, hence its name. Fig. 38 shows a UHF version of this antenna. This is a stacked-"V", since two sets of dipole elements are used. Two other versions of stacked-Vee antennas, suitable for VHF and UHF operation, are pictured in Fig. 39.

This antenna is most popular in areas close to the station, particularly in areas where both VHF and UHF stations are in operation. It will easily cover the entire UHF band, but it does not offer sufficient gain for use in outlying areas.

The antenna elements must be of sufficient diameter to provide the necessary strength against wind, sleet and
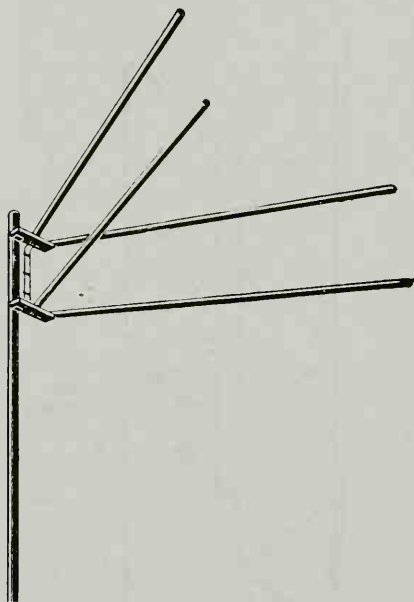

Fig. 38. A commercial broad-band
UHF stacked V-type antenna.

snow, but for most practical purposes a diameter of from three-eighths to one-half inch have been found to be satisfactory.

The gain of the "V" antenna is dependent on the leg length and on the angle the two legs make with each other. Since gain increases almost directly with the leg length and the angle the two legs make with one another, it would seem advisable to make each leg as long as possible. However, in extending the leg length, the antenna structure will become increasingly unwieldy, resulting in breakage when exposed to wind, ice or snow.

A good average in leg length is between fifty and sixty inches, with fifty-five inches as a final compromise figure. It will be noted that this is close to a quarter wavelength for channel 2, 2.1 wavelengths at 450 MHz, and 4.2 wavelengths at 900 MHz. The best suitable "V" angle (angle between the legs) lies between forty and sixty degrees, and the compromise angle of fifty degrees is most frequently employed.
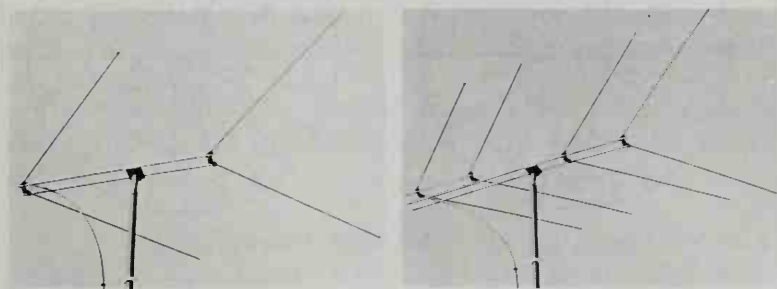
Courtesy Ward Products Corp.

Fig. 39. Two commercial versions of VHF-UHF stacked V-type antennas.

The "V" antennas are stacked approximately one-half wavelength apart at the lowest operating frequency and connected with a 300-ohm transmission line which serves as a phasing and matching network. The 300-ohm tubular lead-in connects to the center of the phasing section. Stacking of the antennas provides additional vertical directivity which is helpful in reducing the effect of ground reflections and makes the antenna positioning for minimum reflections less critical.

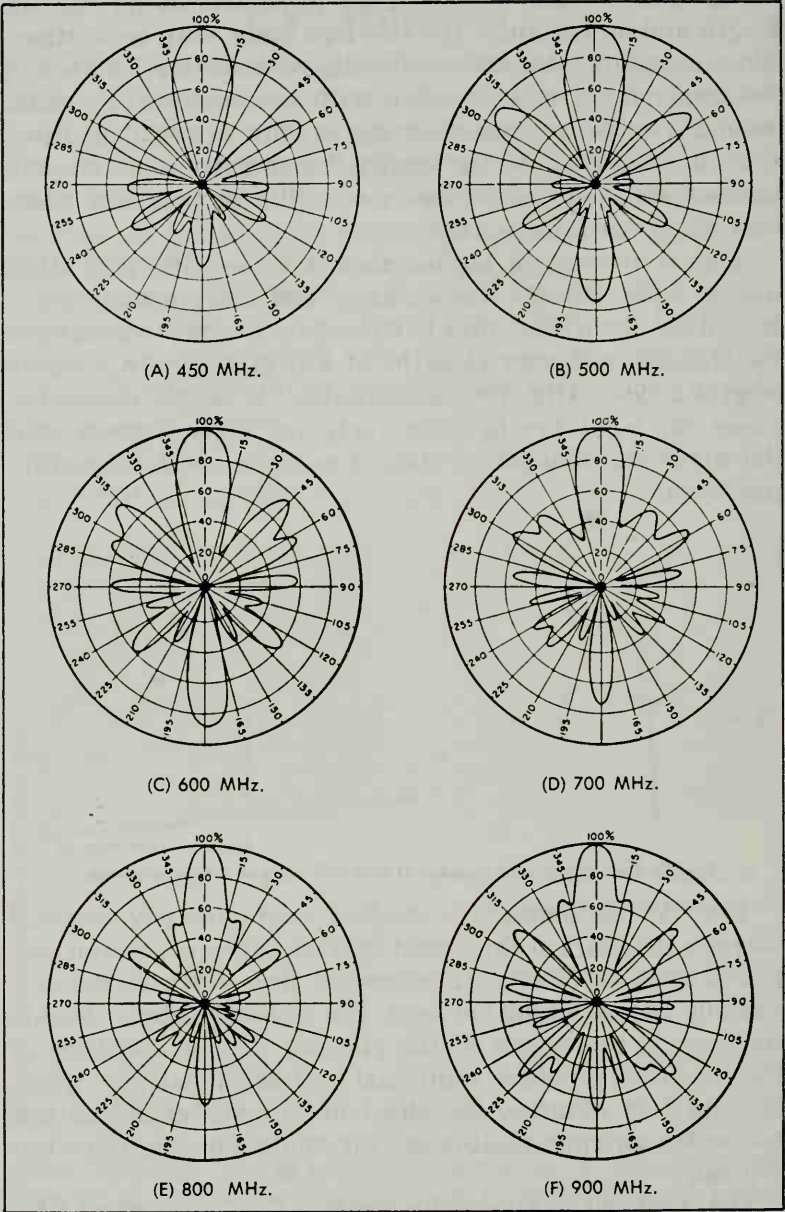The horizontal directivity patterns of a stacked "V" type antenna throughout the UHF band are shown in Fig.

Fig. 40. Horizontal directivity pattern of stacked V-type UHF antenna.

40. The patterns have a number of secondary lobes which become more numerous and rotate away from the forward lobe as the frequency is increased. Multilobed polar patterns are typical of long-wire antennas such as treated here. The length of the "V" elements must be increased several fold to reduce the amplitude of the secondary lobes.

RHOMBIC ANTENNA

Another type of antenna is known as the *rhombic*. It is characterized by high gain and directive characteristics.

To obtain the best results with this type of antenna, the legs of the rhombic should be made at least three wavelengths long for the low-band VHF channels and five wavelengths long on the high-band VHF channels. Where two-band VHF coverage is required, a high-band rhombic can be strung inside a low-band rhombic from the same supports. The separation will be sufficient to avoid undesirable interaction.

The schematic of a rhombic antenna for VHF bands is shown in Fig. 41. Typical dimensions for this antenna are as follows:

	Compact Antenna		Long-Legged Antenna	
Dimension	Low Band	High Band	Low band	High band
A	45.5 ft.	16.0 ft.	102.0 ft.	36.1 ft.
B	35.5 ft.	12.5 ft.	53.2 ft.	18.9 ft.
C	28.9 ft.	10.2 ft.	57.6 ft.	20.5 ft.

It should be noted that the compact antenna will not provide as much gain as the long-legged version.

Because of its dimensional requirements, the space required for erection of a VHF rhombic-type antenna is somewhat of a handicap, particularly where the home is located on a small area of land.

In the construction of a VHF rhombic the first step is to estimate just how many wavelengths on a leg can be erected
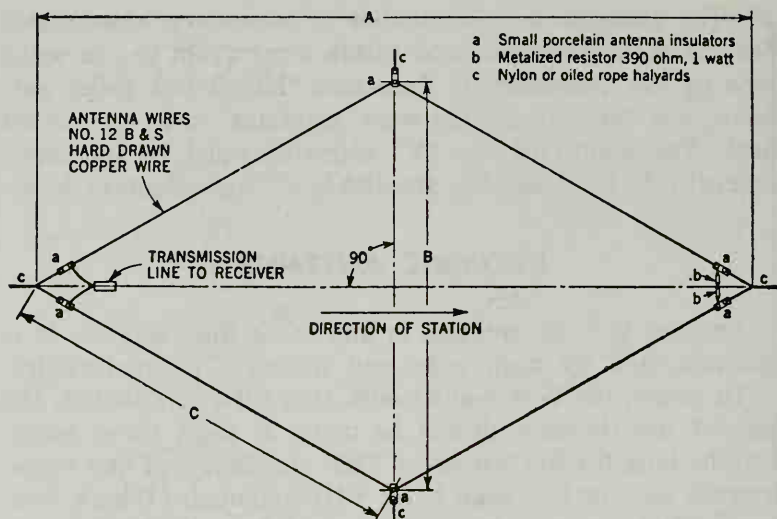
Fig. 41. Schematic of a VHF rhombic antenna for unidirectional reception.

in the space alotted. The greater the number of wavelengths, the sharper and more sensitive the antenna will be.

The next step is the orientation; that is, the array should be pointed in the exact direction of the transmitter. This can be determined by means of a suitable map and an accurate compass.

For proper operation an array must be terminated in a substantially nonreactive resistance of 800 ohms. Satisfactory operation will be obtained by simply connecting in series two 390-ohm metalized resistors of the hermetically sealed type shown in Fig. 41. Two in series are preferable to a single resistor having twice the resistance. Care should be taken to make sure that the resistors used are not of the wirewound type.

Only about 10-percent loss in signal voltage will result if a rhombic array is fed directly into a 300-ohm line without benefit of a matching transformer. Therefore, while it is possible to construct a matching arrangement which will result in a precise match, the improvement hardly can be considered worth the trouble.

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Fig. 42 illustrates a typical UHF broad-band rhombic antenna. The length of each of the four sides shown (also termed legs) should be at least several wavelengths; for this particular antenna shown, a leg is 55 inches. Thus, at a frequency of 470 MHz, one wavelength equals approximately twenty-four inches and two wavelengths would be forty-eight inches.

The antenna elements should have a diameter of approximately one-half inch, and the included angle will vary with the length of the legs. Thus, for example, for legs which are two wavelengths long, the including angle is eighty degrees; for legs three wavelengths long, the angle is sixty degrees; and for antennas having leg lengths of four wavelengths, the included angle is fifty degrees.
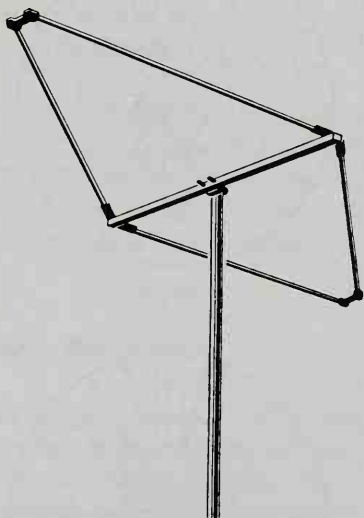
Fig. 42. A commercial UHF broad-band rhombic antenna.

If the wires opposite the transmission line connection are simply connected together, the antenna is bidirectional; but if, as is more usual, a carbon resistor having a value of 470 to 500 ohms is inserted at this point, the response pattern becomes unidirectional.

The input impedance of a transmission line terminated in its characteristic impedance is equal to this characteristic
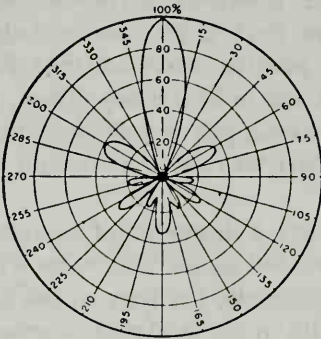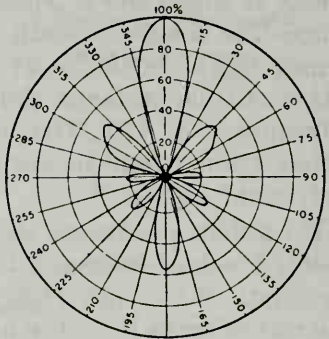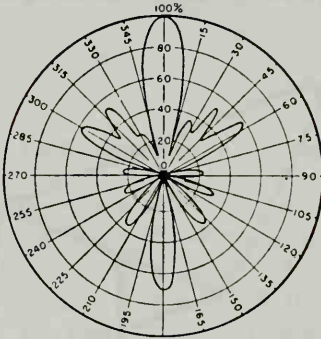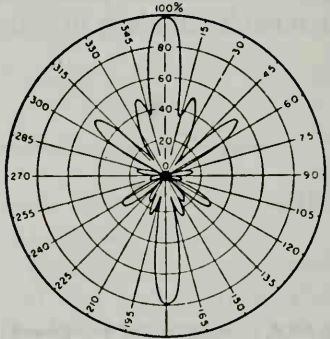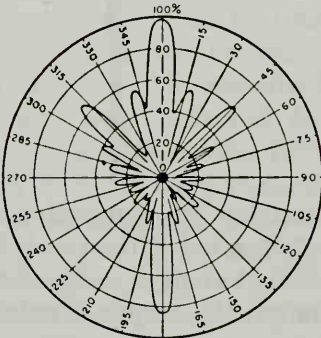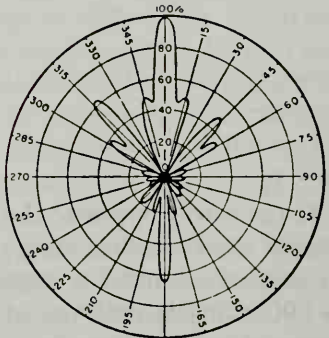
Fig. 43. Horizontal directivity patterns for rhombic antennas.

impedance for all frequencies. If the transmission line is separated in such a manner as to form the terminated rhombic, the input impedance is changed because the configuration of the conductors is different. The input impedance is no longer independent of the frequency; however, by careful adjustment of the termination, it is possible to obtain an input impedance which fluctuates very little with frequency.

Fig. 43 shows the horizontal directivity patterns of the rhombic. It will be observed that the main lobe is extremely narrow throughout the UHF spectrum. The beam width at the low-frequency end of the band is approximately 22 degrees wide at the half-power point. As the frequency increases, the beam width becomes less and, at 900 MHz, is about eleven degrees. Thus, the outstanding characteristic of the rhombic type of antenna is its ability to produce narrow-beam horizontal directivity patterns over a wide frequency range.

Stacking of a rhombic can be employed for increased gain in the manner of other arrays. Separation of one-half wavelength is recommended. This antenna is simple to construct, has good gain, operates over a wide frequency range, and is not critical as to dimension or adjustments.

CORNER REFLECTOR ANTENNA

The parabolic-reflector type of UHF antenna has found increased use in weak signal areas. A more familiar application of the parabolic-reflector principle is found as a well-known part of many light fixtures, where it is employed for concentration of light beams.

This useful property when utilized for concentration of UHF television signals has provided several antennas of various design for both transmission and reception.

Because of the somewhat difficult design principles involved in the construction of a parabolic antenna, tests have shown that instead of using curved surfaces, it is possible to

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use two flat surfaces which are so placed as to intersect each other at some suitable angle, forming a corner. An antenna of this type, known as the corner reflector, is shown in Fig. 44.

The reflector grids have an included angle of ninety degrees and are made from hard aluminum tubes; other materials such as wire fencing can be used if desired, providing the wire spacing is small in comparison to a wavelength. The driven element usually a dipole antenna, is placed at the center of this corner angle and at some distance from the vertex of the angle. The elements are supported near their centers with ceramic insulators in order to minimize the effect of rain, snow, and ice.
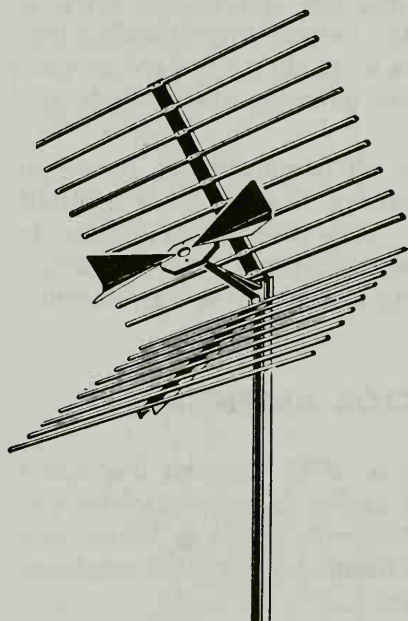
Fig. 44. A UHF corner-reflector antenna.

The response pattern of the antenna depends not only on the corner angle but also on the distance between the antenna and the vertex of the reflector corner. When this distance is large, that is large in comparison to the wavelength used, a pattern containing more than one main lobe is ob-

(A) Spacing too small.   (B) Spacing too great.
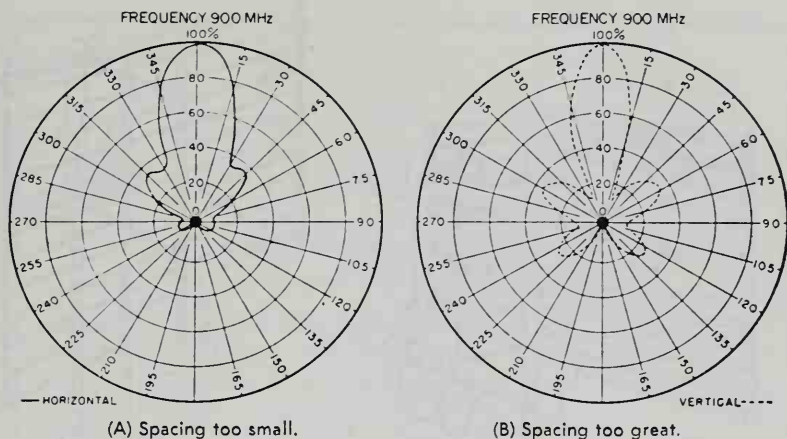
Fig. 45. Effect of spacing between dipole elements and reflector on directivity
pattern of UHF corner-reflector antenna.

tained as shown in Fig. 45. Moving the antenna in too close
will affect the vertical response of the array and make it
more susceptible to ground reflected signals. Since neither
of the foregoing conditions are desirable, the exact posi-
tioning of the dipole must be obtained.

The corner angle of a commercial array illustrated in
Fig.42 is, as previously noted, ninety degrees. A similar
bend is included in the dipole element. The reflector-bar
spacing must be controlled within one-fifth of a wavelength
at the highest frequency at which the corner-reflector an-
tenna is to be used.

PLAIN REFLECTOR ANTENNAS

Reflector antennas for UHF reception quite frequently
take the form shown in Fig. 46. Although these two anten-
nas differ somewhat in construction, their directivity pattern
and cost of construction are approximately the same.

Each antenna is equipped with two stacked dipoles and
a sheet reflector made of a series of rods. A phasing section
connects the two dipoles, and the transmission line is fed at
the midpoint of the phasing section.
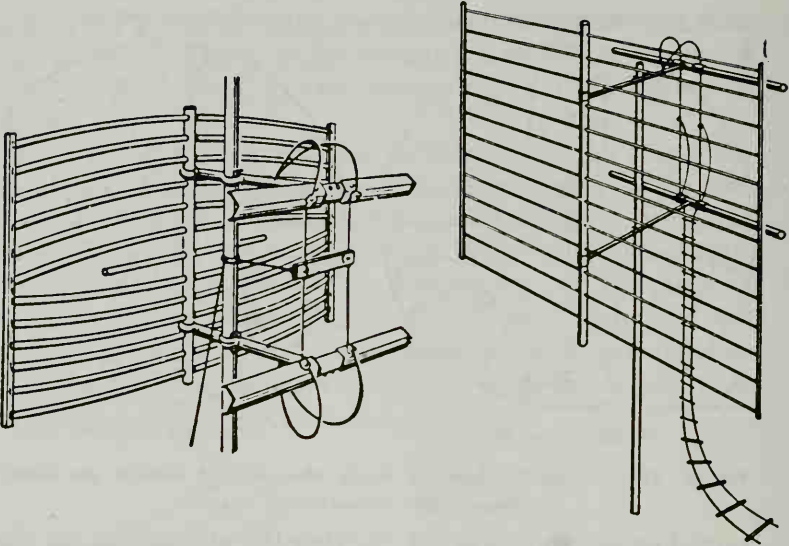
Fig. 46. Two VHF stacked-dipole antennas with reflector screens.
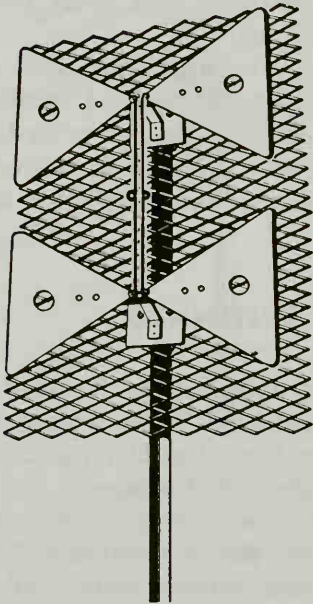
Fig. 47. Stacked triangular dipole antenna with mesh reflector screen.
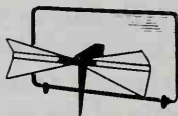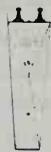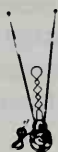
(A) Primary areas—up to 10-12 miles.
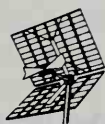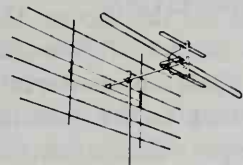
(B) Secondary areas—up to 50 miles.
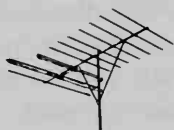
(C) Fringe areas—50 to 75 miles.
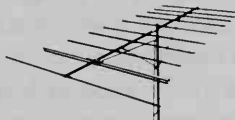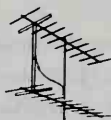
(D) Far-fringe areas—over 75 miles.

Fig. 48. Types of antennas for areas of different signal strengths.

The addition of a reflector to an antenna serves several purposes. It reduces or substantially eliminates reception of any signals approaching the array from the reflector side. This converts a bidirectional antenna into one which can receive signals from essentially one direction. It also increases the gain of the array in the remaining direction.

Mesh screens serve as well as rods or solid sheets for reflectors. For example, a triangular dipole antenna with a mesh screen is shown in Fig. 47. Except for the screen, this antenna is similar to the ones in Figs. 34 and 37. The fact that there are openings in the screen does not materially affect its performance as a reflector as long as the openings do not exceed two-tenths of a wavelength. Dimensions of the reflector are not critical, but the edges should extend for a short distance beyond the dipole elements.

ANTENNA SELECTION

The selection of the proper antenna for a given location is dependent on many factors. Perhaps the primary concern is the distance from the station and the signal strength available. In metropolitan areas, satisfactory reception of VHF signals can usually be obtained from a built-in or indoor antenna. For UHF reception in metropolitan areas, the built-in or indoor antenna may give satisfactory reception; however a more elaborate antenna system is usually required for color reception than is needed for black-and-white reception.

As the distance between the transmitter and receiver is increased, antennas with more gain are necessary. This is illustrated in Fig. 48.

Another consideration in selecting the proper antenna is the number of channels available. For example, if both VHF and UHF channels are available, an antenna suitable for both bands (such as a "V") should be used if sufficient signal strength can be obtained with it.

If high- and low-band VHF channels are available, the conical antenna is very popular. For fringe areas, all-chan-

nel Yagis are available. However, in extreme fringe areas, an antenna cut for the channel desired must usually be employed. Sometimes antennas must be stacked to obtain sufficient signal strength. Also, it may be necessary to use separate antennas for each channel.

ANTENNAS TROUBLESHOOTING

The most common trouble symptom produced by an antenna is weak, snowy, or no picture reproduction on some or all channels. Note that sound is often satisfactory, even when the picture is very weak or absent. This occurs because the sound signal has a comparatively high level, and the receiver provides high gain in the sound channel. Inspection of the antenna might show, for example, that one or both of the lead-in conductors have broken loose from the antenna, or that the lead-in has become damaged at some point. Lightning damage can melt a lead-in conductor, usually at a point where the stroke arcs to grounded objects. Although a lead-in that is not connected to the antenna will pick up more or less signal, its response is unpredictable. In most cases, all channels are weakened, but in exceptional cases most channels might be weakened, with stronger reception on one or two channels.

If a folded-dipole construction, or equivalent, is used in the antenna, the system can be checked for continuity with an ohmmeter. However, the ohmmeter will not read 300 ohms; only the dc resistance of the conductive path is indicated. An infinite reading shows that there is an open circuit. A very high resistance reading shows that there is a poor connection. Antennas of the basic open-circuited type can be checked out with a capacitance bridge. In other words, twin lead has an established capacitance per foot, and standard antennas have an established terminal input capacitance. Therefore, the experienced technician can figure the length of the lead-in, and knowing the input capacitance of the antenna, can measure the total capaci-

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tance to determine if there is an open-circuit at some point in the system.

Sometimes an antenna system becomes intermittent, and the picture varies erratically from time to time. In most cases, the trouble symptom is most annoying in windy weather. Intermittents are the most difficult faults to locate, and sometimes it is most expedient to simply replace the lead-in (and antenna also, if it is in badly deteriorated condition). It is good practice to install lead-in securely, so that it does not whip or swing in the wind. Not only will this precaution stabilize picture reproduction on the high frequencies, but it will also prevent metal crystallization and eventual failure.

SUMMARY

There are basically five classes or types of television antennas. They consist of built-in antennas for primary areas (up to 10-12 miles), to outdoor antennas for far-fringe areas of 75 miles and over. The quality of the picture that is reproduced on the screen of a television receiver is dependent on many factors, but the antenna plays a very important part in normal television reception.

The transmission of a television picture signal acts quite similar to rays of light; the signal will not bend around corners and is not reflected by obstacles in this path. Therefore, television waves do not follow the curvature of the earth and reliable reception should only be anticipated in the region determined by the line of sight to the horizon in all directions from the antenna tower of the transmitting station.

The United States uses a positive transmission signal. England uses a negative transmission; therefore the TV signals must be converted before either country can utilize the transmission. Various foreign countries transmit TV signals with more lines in some instances, and with fewer lines in other instances than the U.S.

Impedance matching of the antenna is a very important factor. When the receiver input matches the impedance of the transmission line, the transmitted signal is completely absorbed and as a result there are no reflections or standing waves on the transmission line, and consequently no ghost. A condition which may easily arise is the mismatch of 300 ohms to 72 ohms. This condition will exist when a 72-ohm antenna is connected to a receiver having a 300-ohm input impedance.

REVIEW QUESTIONS

1. Name the 5 classes of television antennas.
2. What are *echoes* or *ghost?*
3. Explain the purpose of the transcontinental television transmission system.
4. What are the 3 factors covering antenna installations?
5. What are the 4 general types of transmission lines?
6. What are *parasitic elements?*
7. What is the advantage of "stacking" the conventional dipole antenna?
8. What is a *reflector? Director?*
9. Why are VHF stations easier to receive than UHF?
10. The United States uses a positive transmission signal. What must be done before England can use our signal?

CHAPTER 6

Antenna Installation

The first step in any antenna installation is an "on-the spot" survey of the location. Look over the house. Note the type of construction (brick, stone, frame, etc.) and the type of roof. Check the location of the TV receiver(s) to be served by the antenna. Decide on the best location for the antenna and the best route for the lead-in. Sometimes the best location for an antenna will be determined by the availability of a good ground. An example of an antenna grounding arrangement is shown in Fig. 1. Observe that the mast is grounded directly, and that the lead-in is connected to a lightning arrestor which in turn is connected to ground. A short and direct connection to an external ground is required by the National Electrical Code, and by local electrical codes.

The actual selection of the type of antenna to be installed will depend on many factors. The distance from the transmitting antenna is of prime importance. Another important factor is the number of channels available. As discussed in the previous chapter, some antennas are suitable for strong signal areas and some for fringe areas, some are suitable for all-channel reception and others for only a single channel. Look around and see what types of antennas are used on neighboring houses, but before installing one of the same type make sure they are obtaining suitable reception.

Most homes have two or more TV sets. Where it is practical, it is logical to use one antenna to serve every set in the house. Fig. 2 shows the simplest way in which this is done,

by using a multi-set coupler. In other cases, people want a TV antenna outlet in every room. This requirement is served best by a home TV system such as depicted in Fig. 3. Technical details are explained later in this chapter.
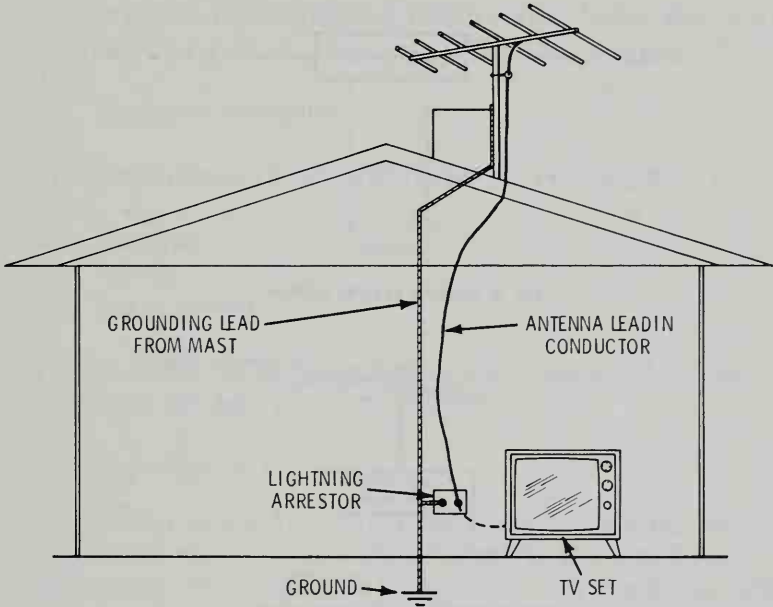
Fig. 1. Example of antenna grounding arrangement.

TOOLS

Of course, one of the first tools needed in any antenna installation is a ladder. Usually a 20-or 24-foot extension ladder is best. Several hand tools are also necessary. No attempt will be made to list all possible tools that may be needed. Each installation job varies, and so do the tool requirements. However, the following is considered as the basic tools required before any installation is attempted.

1. Assortment of No. 6 and No. 8 screwdrivers.

2. Six-inch slip-joint pliers.
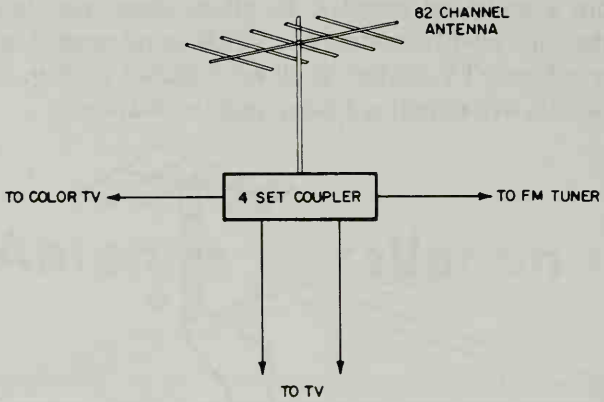
Fig. 2. Antenna coupler splitter.
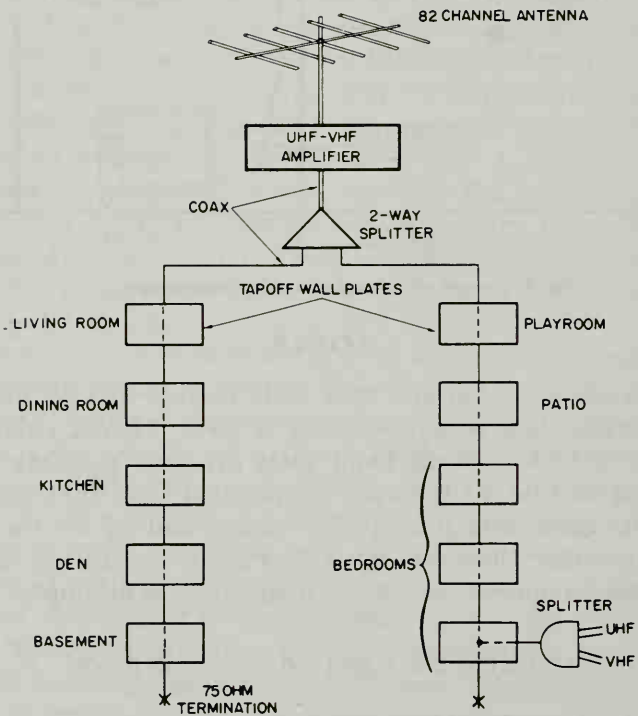
Fig. 3. Small master antenna system.

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3. Long-nose pliers.

4. Diagonal cutting pliers (for lead-in).

5. Six-inch case-hardened cutters (for bolts, guy wire. etc.).

6. Open-end wrenches.

7. Nut drivers (1/4", 3/8", 5/16", 7/16", and 1/2").

8. Hammer.

9. Large punch.

10. Assortment of wood bits (should contain 1/2" but at least 12" long).

11. Brace for bits.

In addition to the foregoing, there are many other useful tools. Socket wrenches are often handy, as is a small adjustable wrench. In addition, a hack saw and a small key-hole saw are often needed. While not a necessity, a 1/4-inch electric drill is very handy. A long extension cord will be needed for the drill. If the house is of brick or masonry construction, some means of drilling a hole in the wall must be available. A star drill (Fig. 4) can be used. These drills

Fig. 4. Two types of star drills.

are hit with a hammer and rotated slightly after each stroke. With each stroke of the hammer, some of the wall is broken

ANTENNA INSTALLATION

loose. This process is continued until the hole is deep enough.

A much easier method of drilling a hole is provided by the carbide-tipped masonry drill bit of Fig. 5. This bit fits in the 1/4-inch electric drill (be sure to get a bit with a 1/4-inch shank). One word of caution: don't force the bit

Fig. 5. A carbide-tipped masonry bit.

in the masonry—take your time. Also, if a hard rock is encountered, it is much easier to break it with a star drill and then proceed to finish the hole with the carbide-tipped bit.

MASTS AND TOWERS

Another decision that must be made in the initial inspection is how to support the antenna. Again one of the primary factors in determining the selection is the distance from the transmitting antenna. In strong signal areas almost any type of installation can be used. In fringe areas, tall towers are usually necessary.

Masts—The tubular mast is the most popular method of supporting an antenna. It can be mounted on a chimney, on the peak of a roof, from a flat roop, attached to the side of the building, or even hung in the attic as shown in Fig. 6. Tubular masts are made of aluminum or steel and are usually sold in 10-foot lengths. The ends are made so that one end will slip into the opposite end of another section so that greater heights can be obtained. If properly guyed, masts up to 50 feet can be employed.

Telescopic masts are also available. In this type of construction, each section fits inside the next lower section. When a section is extended a locking mechanism holds it in place. Telescopic masts are available up to 50 feet in length.

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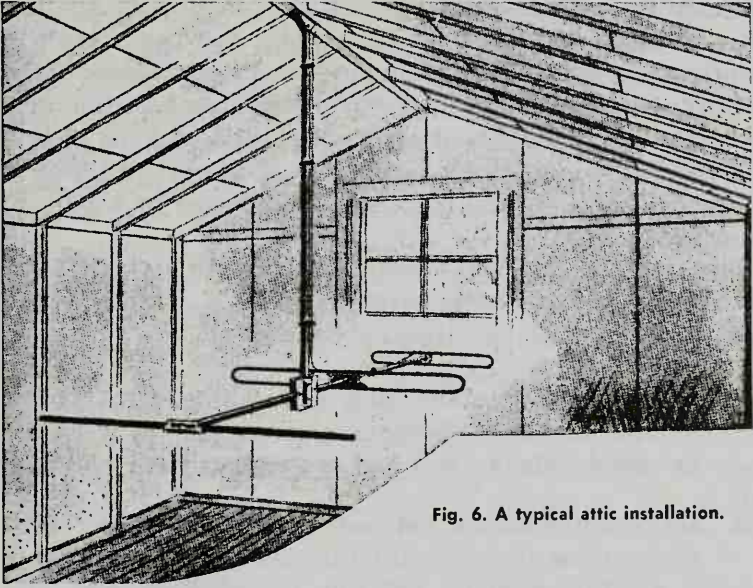
Fig. 6. A typical attic installation.

Towers—Where greater heights, or a sturdier installation, is necessary, the triangular steel tower is used. Towers are available in 6- or 10-foot sections which are bolted together to obtain the necessary height. A typical fringe-area
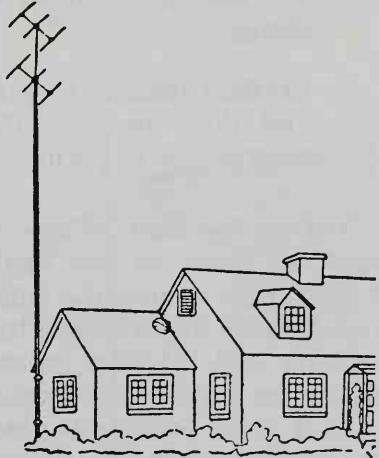
Fig. 7. A typical fringe-area antenna installation.

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installation, utilizing a tower is shown in Fig. 7. Another type of tower is hinged in the middle and has a built-in winch which is used to tilt the top over to gain access to the antenna. In still a different type of tower, each section gets progressively smaller as it approaches the top. Each section fits inside the next lower section. Thus the entire tower is telescoped together and is raised and lowered by a built-in winch at the base.

Locating the Antenna—Before attempting to install the antenna, it is essential to carefully select a position which allows the following conditions to be fulfilled:

1. Absence of obstruction such as buildings, trees, power lines, other nearby antenna systems, etc., between the proposed antenna site and the transmitting antenna.

2. Maximum distance between proposed antenna sites and sources of electrical noise such as might originate in ignition systems, elevator relays, diathermy and X-ray machines, and arcing from electrical transit systems. Several of these conditions preclude the possibility of mounting the antenna near the edge of the roof adjoining a street with heavy traffic even though this site may be preferable with respect to length of antenna lead-in.

3. Greatest possible height above ground level. In general this will allow the antenna to overcome such obstructions as are mentioned in item 1.

Before the mast or tower is actually installed, a preliminary check of the location choice should be made. Temporarily connect the antenna to a mast and attach the transmission line. Connect the transmission line to the TV receiver and hold the antenna in the chosen location to determine if a suitable signal is obtained.

It is often possible to obtain considerable improvement in performance by moving the antenna location a small

distance from the original site. This final test for the most desirable antenna location becomes vitally important in areas where signal strength is low or where reflection from surrounding surfaces produce multiple transmission paths, thereby creating multiple images or "ghosts" on the screen.

By now it should be obvious that an antenna installation requires two men. One can hold the antenna while the other observes the effect on the screen. Some means of communication between the two is necessary. Sound-powered telephones are very helpful for this purpose. Lacking this, a third person can stand outside a window or door and relay messages between the man at the antenna and the one observing the receiver.

Mast Installation—Various methods are used for mounting antenna masts. For short masts, brackets can be used to attach it to the wall or eave as shown in Fig. 8. In
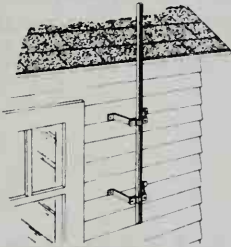
(A) Wall mount.
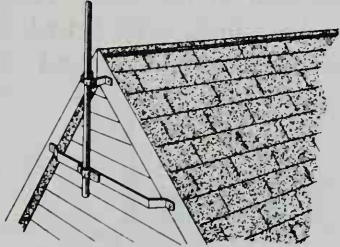
(B) Eave mount.
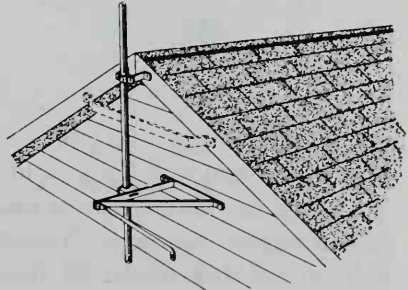
(C) Combination wall and eave mount.

Fig. 8. Wall and eave mounts.

addition, there are many versions of the chimney mount (Fig. 9). Before mountings of Fig. 8 or 9 are attempted, be sure to check the wall or chimney. Make sure they are in good condition so they will be able to withstand the added strain placed on them by the antenna. During a windstorm or in the winter in the northern areas when the antenna and mast are coated with sleet, enormous pressures are exerted on the installation.

The spacing between the brackets should be sufficient to hold the mast rigid. This distance will vary with the mast height.

A mast support suitable for a peaked roof is shown in Fig. 10. Supports very similar to this can also be used for flat-roof installations. In either case, it is usually necessary to install guy wires for additional support.

Masts can also be based on the ground and extended above the roof top. Some method of solid support must be provided at the base. This support can be provided by a cement block, solid board, or even a flat rock. A pipe strap should be placed around the mast at the eave or gable of
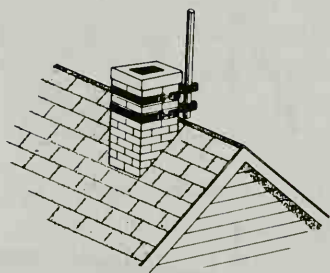
Fig. 9. A chimney mount.

the house. If the mast does not extend for more than 10 feet above this point, no additional supports are required. This type of installation is one of the most popular and one of the easiest to make. Telescopic masts, which are available in heights up to 40 feet, are usually employed. Just enough slack should be allowed in the strap to allow the mast to be turned but the strap should exert enough pressure
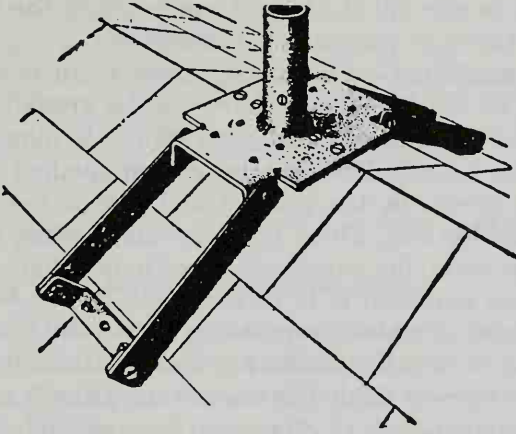
Fig. 10. An antenna mount suitable for a peaked roof.
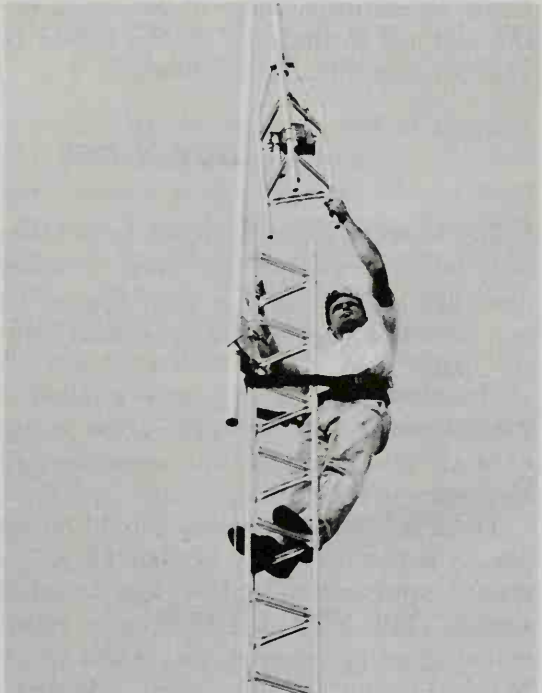
Fig. 11. A safety belt being worn while working on a tower.

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on the mast to prevent the wind from twisting the antenna. Thus, orientation of the antenna is simplified.

Tower Installation—-Like masts, towers can be mounted on the roof or on the ground; however the ground installation is more popular because of the difficulty in manipulating the tower on a roof. Perhaps the easiest method is to assemble the tower on the ground and attach the antenna and transmission line. Then, with one man on the roof and two on the ground, the antenna is lifted to position.

Sometimes, however, it is necessary to install the tower section by section while the installer climbs the tower. Guy wires should be installed in their proper locations before the installer attempts to climb the tower (more about guy wires later). *Never* attempt to climb an unsupported tower. A safety belt (Fig. 11) is a necessity when working on a tower because both hands will be needed for connecting the sections. In addition, some means must be employed to raise the sections to the man on the tower. Gin poles are available for this purpose as shown in Fig. 11.

GUY WIRES

Guy wires must be attached to practically every antenna installation to support the mast or tower. The only exceptions are self-supporting steel towers set deep in concrete and eave installations which extend only a few feet above the roof.

The most popular guy wire is 6/20 steel (6 strands of No. 20 gauge steel wire). Heavier wires, such as 6/18 and 6/14 are also available, and sometimes aluminum instead of steel wire is used.

Three or four guy wires should be used at each guying point. In the three-guy system (Fig. 12A), guy wires are spaced approximately 120° apart; while in the four-guy system (Fig. 12B), the spacing is approximately 90°. The actual spacing between guy wires must depend upon the physical layout at the location. Likewise, the spacing along

(A) Three-guy system.   (B) Four-guy system.
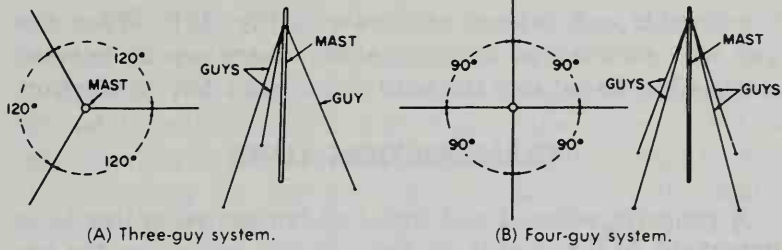
Fig. 12. Method of placing guy wires.

In general, separate guy-wire systems should be attached for each 10-ft. in height for masts. For towers, attach guy wires for each 10 or 12 feet of height. In either case, they can be spaced closer if necessary. In areas where high wind velocities or severe winter are expected, extra guy wires are indicated.

Rings which fit over the mast are available for attaching the guy wires. For towers, rings which fit over each leg, are used. These rings should be slipped over the legs as the tower is assembled.

The type of anchor used at the opposite end of the guy wire will depend on the location. Flat steel plates with one end bent up at approximately a 45° angle should be used for anchoring guy wire on walls or flat surfaces. Screw-in eyes are available for roof installations. Anchorages can be attached to trees (use a screw-in device, never wrap wire around tree) or even to stakes driven in the ground.

Do not attach the guy wire directly to the ring on the mast or tower to the anchorage. Instead a thimble (Fig. 13A) should be inserted first. The wire is inserted around

(A) Thimble.   (B) Guy wire tied to thimble.
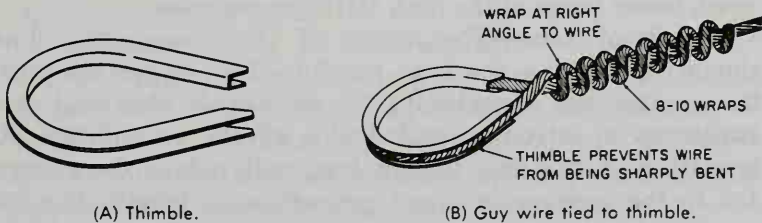
Fig. 13. Use of a guy-wire thimble.

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the thimble and twisted as shown in Fig. 13B. When the guy wire is attached in this manner, there are no exposed sharp edges to cut into the wire and weaken the installation.

TRANSMISSION LINES

A properly selected and installed transmission line is as important to the quality of the antenna system as the antenna itself. An improperly installed line causes reflection (ghosts) and high losses. Reflections in the line make it impossible to obtain clear pictures, and in severe cases, the reflection cause "smears" so that the picture appears out of focus even though the receiver is perfectly focused. In general, the longer the transmission line, the more care required in installation.

Most television receivers have a 300-ohm input circuit which is intended for connection to a 300-ohm antenna system. Failure to observe proper impedance match between antenna, transmission line, and receiver will result in less energy delivered to the receiver, and undesirable effects of noise and interference may be accentuated.

Types of Transmission Line—Low-loss, ribbon-type, flat, 300-ohm transmission line is intended for use in a normal installation. However, under conditions where man-made interference may be picked up by the transmission line itself, shielded coaxial cable may be used to alleviate this condition. Since coaxial cable is normally not available with a 300-ohm impedance, impedance-matching devices should be used. For UHF installations tubular twin-lead transmission line is recommended. This type of line presents much lower losses at the high UHF frequencies.

Length of Line—The length of the transmission line should be kept as short as possible. The longer the line, the greater the opportunity for man-made electrical disturbances to introduce undesirable effects. In addition attenuation of the line, though low, will reduce the energy fed to the receiver in direct proportion to length. For extremely long runs, open-wire transmission line should be

used. This type of wire has the lowest loss; however, it has the disadvantage of being hard to work with.

Splicing the Line—If it becomes necessary to splice on an additional length of ribbon-type line, care should be exercised to avoid a mismatch at the splice. This is done by stripping the two lines back about one inch making sure the insulation is cut as shown in Fig. 14A. Then twist

(A) Strip wires.

(B) Twist and solder.

(C) Bend wires back and tape.
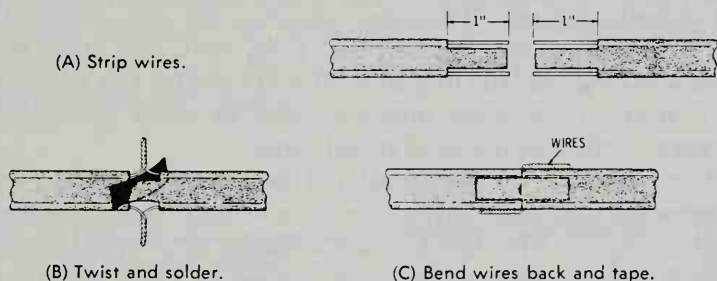
Fig. 14. Proper method of splicing twin-lead line.

the respective conductors together so that the insulation of one lays directly against the insulation of the other (Fig. 14B).

If the splice is made with too large or too small a space between parallel wires, the line impedance will be changed at this point and serious reflections may occur. The twisted pairs should be soldered, avoiding excessive heating which will soften the insulation. Bend the protruding solder joints back along the line, lap the center insulation, (Fig. 14C) and cover the splice with an insulating tape intended for high-frequency purposes.

Polystyrene blocks are also available for splicing twin lead. For this type of splice, a short length of each lead is stripped back and inserted into the block. Then set screws in the side of the block are tightened against the wires, making soldering unnecessary. Some splicing blocks are constructed as a matching plug and socket. Hence, they can be quickly disconnected and connected to different points.

Splicing of coaxial cable is not recommended; use special connectors available for that purpose.

Routing and Securing—It is well to carefully consider the best route for the transmission line with respect to length and electrical disturbance shielding. A compromise must usually be made on the length so as to be able to take advantage of the shielding effect of the building against such disturbances as ignition noise and arcing from electrical transit systems. Whenever possible, the line should be run in a vertical direction so that rain, sleet, and snow will have less tendency to cling to it. If a horizontal run is necessary, it should be made under an eave or other protection. Never run the line inside of metal pipes.

The transmission line must not be allowed to make extensive contact with any surface (especially metal). Standoff insulators (Fig. 15) provide a means of supporting the line as well as maintaining proper spacing from surrounding surfaces.

The standoff pictured in Fig. 15 are designed for mounting in wood (left) or on the mast (right). Other types of standoffs are constructed for mounting in almost any sur-
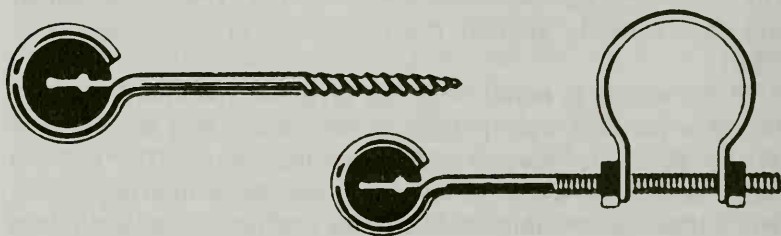
Fig. 15. Standoff insulators.

face. There is even one for driving into cement walls. Shafts of various lengths are also available to suit any need.

Standoff insulators should be placed approximately 5 feet apart along the line. However the actual locations will depend upon the location of physical obstructions and the route the line must take.

The insulator should grip the transmission line and support it in both the vertical and horizontal direction. To at-

tach the line to the standoff, insert the line in the slot then twist the inner insulating material so that the slot opening is positioned at the rear of the metal eye as shown in Fig. 16. The line should be pulled tight so that a heavy wind will not cause it to swing against surrounding objects and then the metal eye should be squeezed so that it tightly grips the inner insulator (hence the line) preventing it from moving. In locations where electrical noise creates an interference problem, the noise pickup may be minimized by twisting the line about one turn per foot between the supporting standoff insulators.

Fig. 16. Method of placing transmission line in standoff insulator.
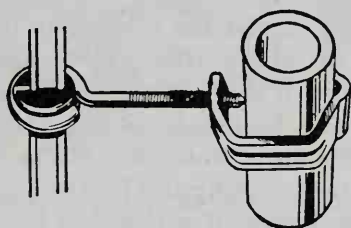
Entering House—Various methods are employed for entering the house. Of course, the window can be raised, the lead-in inserted and the window lowered. However, this method is far from satisfactory. If the window is metal or metal flashing is employed along the window, the metal will create a short across the two wires of the twin lead—thus shorting out the antenna. In addition, raising and lowering the window will wear away the insulation and break the wires of the leads.

Special entrance fittings are available. A 1/2-inch hole is drilled through the wall and the device inserted. The lead-in is then inserted through the device which also seals the hole to prevent cold or rain from entering. Such a device can be installed directly behind the desired location for the receiver. Thus the receiver will hide the entrance fitting from view. Some are equipped with a socket at the inside end for attaching the lead-in to the receiver.

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Another method of entrance is to enter under the floor through a ventilation opening or hole drilled for this purpose. The lead-in is then run under the house to the desired location. Use short standoff insulators to support the lead-in.

Two 1/4-inch holes, drilled side-by-side behind the quarter round provide an easy neat-appearing method of entering the room above. Pull the quarter round back before drilling the holes. Then if it is ever desired to change the location, the lead-in can be removed and the quarter round hides the holes.

Special wall plugs can be used as a means for connecting the transmission line to the receiver. The lead-in can be run under the floor or in the attic to a point directly below (or above) the desired location. Then a hole is drilled between the walls and a cutout made for the wall receptacle. The lead-in is routed through the hole to the receptacle opening. Note: fire blocks within the wall will usually prevent routing the lead-in from the attic to a wall receptacle; however, if a closet is located behind the wall, the lead-in
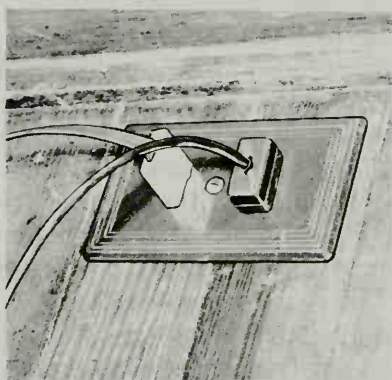
Fig. 17. A combination plate with antenna lead-in and rotator socket mounted in the floor.

can be run through the closet to the receptacle. If desired, the antenna receptacle can be mounted directly in the floor as shown in Fig. 17. Such an installation is easier to make because the necessity for drilling holes between the walls is eliminated; however, a hole must be cut in the flooring.

In addition to the TV antenna outlet, antenna receptacles may also provide outlets for rotator cables or an FM antenna. The unit pictured in Fig. 18 has an outlet for the TV and an FM antenna as well as the regular AC power outlet.

Fig. 18. A combination TV and FM antenna wall socket with AC outlet.
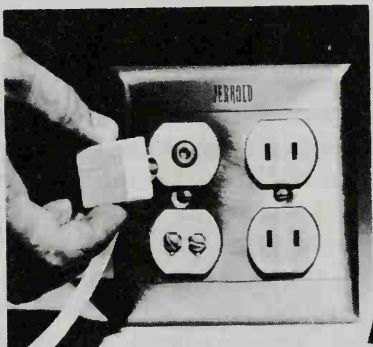
Outlets can be installed at several locations within the house. However, if more than one receiver is to be operated at once, some means of isolation is usually necessary (described later). Even when only one receiver is being used at a time, the length of the transmission line to the other outlets may sometimes cause an adverse effect on the signal. When this happens, a connector can be installed directly inside the point where the antenna enters the house and only the desired outlet connected to this point or a multiple-set connector can be used.

When routing the line inside or under the home, it should be routed by the shortest possible path to the receiver, taking special precaution to avoid contact with pipes, radiators or other metal objects.

Connecting Line to Receiver.—A terminal strip will be found on the rear of the receiver cabinet. Connect the transmission line to these terminals. If a wall or floor receptacle is used, fasten a plug which matches the socket to a short length of transmission line. Connect one end of the transmission line to the terminal strip on the rear of the receiver and insert the plug in the socket.

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GROUNDING

No antenna installation is complete until it has been properly grounded. Unless the mast or tower is buried in the ground, a ground wire must be run from it to a suitable ground. Cold-water pipes, underground tanks or other "metallic underground systems" are considered as suitable grounds. A ground rod can be driven in the ground and connected to the tower. Such a rod should be a 5/8-inch diameter, 8-foot long, copper-plated steel rod.

In addition, a lightning arrester should be placed at the point where the lead-in enters the building. Numerous approved types are available. All have some means whereby two contacts are placed in close proximity to the line. Then a ground wire is run from another terminal to the ground rod. The National Electrical Code states that separate grounds should be employed for each portion of the system; however, if the lightning arrester is connected directly to
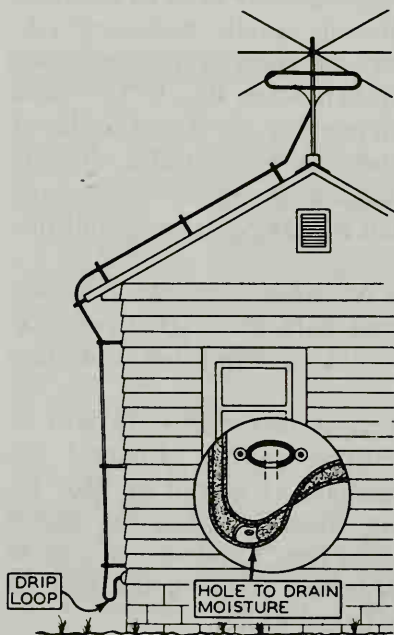
Fig. 19. A drip loop in
the antenna lead-in.

DRIP
LOOP

HOLE TO DRAIN
MOISTURE

the mast or tower, a single ground can be used. In addition, where separate grounds are employed, each of these separate grounds should be connected together by a separate interconnecting ground wire.

Always leave a loop between the last standoff or lightning arrester and the point where the lead-in enter the house. This is shown in Fig. 19. This loop prevents water from running down the line and inside the house. If tubular twin lead is being used, punch a hole in the bottom of the loop (as shown in the inset) to allow any moisture which may have entered the line to drip out.

CODE SPECIFICATIONS

Article 810 of the National Electrical Code gives the specifications for safe installation of antenna systems for radio and television receivers. Portions of this code are given in the following:

ANTENNA SYSTEMS—GENERAL

810-11 Material—Antenna counterpoise and lead-in conductors shall be of hard-drawn copper, bronze, aluminum alloy, copper-clad steel or other high strength, corrosion-resistant material. Soft-drawn or medium-drawn copper may be used for lead-in conductors where the maximum span between points of support is less than 35 feet.

810-12 Support—Outdoor antenna, counterpoise, and lead-in conductors shall be securely supported. They shall not be attached to poles or similar structures carrying electric light or power wires or trolley wires of more than 250 volts. Insulators supporting the antenna or counterpoise conductors shall have sufficient mechanical strength to safely support the conductors. Lead-in conductors shall be securely attached to the antenna.

810-13 Avoidance of Contacts with Conductors of Other Systems—Outdoor antenna, counterpoise, and lead-in conductors from an antenna to a building shall not cross over

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electric light or power circuits and shall be kept well away from all such circuits so as to avoid the possibility of accidental contact. Where proximity to electric light and power service conductors of less than 250 volts cannot be avoided, the installation shall be such as to provide a clearance of at least two feet. It is recommended that antenna and counterpoise conductors be so installed as not to cross under electric light or power conductors.

810-14 Splices—Splices and joints in antenna and counterpoise span shall be made with approved splicing devices or by such other means as will not appreciably weaken the conductors. (Soldering may ordinarily be expected to weaken the conductor. Therefore, the joint should be mechanically secure before soldering.)

810-15 Grounding—Masts and metal structures supporting antennas shall be permanently and effectively grounded, without intervening splice or connection.

ANTENNA SYSTEMS—RECEIVING STATION

810-16 Size of Wire-Strung Antenna—

    (a) Outdoor antenna and counterpoise conductors for receiving stations shall be of a size not less than given in the following table:

Material	Minimum size of conductors when maximum open span length is		
	Less than 35 ft	35 to 150 ft	Over 150 ft
Aluminum alloy, hard-drawn copper	19	14	12
Copper-clad steel, bronze or other high strength material	20	17	14

(For very long span lengths larger conductors will be required, depending on the length of the span and the ice and wind loading.)

      (b) Self-Supporting Antennas—Outdoor antennas, such as vertical rods or dipole structures, shall be of noncorrodible materials and of strength suitable to withstand ice and loading conditions, and shall be located well away from overhead conductors of electric light and power circuits of over 150 volts to ground so as to avoid the possibility of the antenna structure falling into or accidental contact with such circuits.

810-17 Size of Lead-In—Lead-in conductors from outside antenna and counterpoise for receiving stations, shall, for various maximum open-span lengths, be of such size as to have a tensile strength at least as great as that of the conductors for antenna as specified in section 8116. Where the lead-in consists of two or more conductors which are twisted together or are enclosed in the same covering or are concentric, the conductor size shall, for various maximum open-span lengths, be such that the tensile strength of the combination will be at least as great as that of the conductors for antenna as specified in Section 8116.

810-18 Clearance—

      (a) On Buildings—Outside. Lead-in conductors attached to buildings shall be so installed that they cannot swing closer than two feet to the conductors of circuits of 250 volts, or less between conductors, or ten feet to conductors of circuits of more than 250 volts between conductors, except that in the case of circuits not exceeding 150 volts between conductors, where if all conductors involved are supported so as to insure permanent separation, the clearance may be reduced but shall not be less than four inches. The clearance between lead-in conductors and any conductor forming a part of a lightning-rod

           system shall be not less than six feet unless the bonding referred to in Section 2586 is accomplished.

   (b)   Antenna and Lead-Ins—Indoors. Indoor antennas and indoor lead-ins shall not be run nearer than two inches to conductors of other wiring systems in the premises unless,

       (1.)   such other conductors are in metal raceways or cable armor, or,

       (2.)   unless permanently separated from such other conductors by a continuous and firmly fixed nonconductor such as porcelain tubes or flexible tubing.

LIGHTNING ARRESTERS

810-20 Lightning Arresters-Receiving Stations—Each conductor of a lead-in from an outdoor antenna shall be provided with a lightning arrester approved for the purpose, except that if the lead-in conductors are enclosed in a continuous metallic shield the lightning arrester may be installed to protect the shield or may be omitted if the shield is permanently and effectively grounded. Lightning arresters shall be located outside the building, or inside the building between the point of entrance of the lead-in and the television set or transformers, and as near as practicable to the entrance of the conductors to the building. The lightning arrester shall not be located near combustible material nor in a hazardous location.

GROUNDING CONDUCTORS—GENERAL

810-21 Material—The grounding conductor shall, unless otherwise specified be of copper, aluminum, copper-clad steel, bronze, or other corrosion-resistant material.

810-25 Run in Straight Line—The grounding conductor shall be run in as straight a line as possible from the antenna mast and/or lightning arrester to the grounding electrode.

GROUNDING CONDUCTORS—RECEIVING STATION

810-27 Inside or Outside Building—The grounding conductor may be run either inside or outside the building.

810-28 Size—The grounding conductor shall be not smaller than No. 10 copper, No. 8 aluminum, or No. 17 copper-clad steel or bronze.

810-29 Common Ground—A single grounding conductor may be used for both protective and operating purposes. (Where a single conductor is so used, the ground terminal of the equipment should be connected to the ground terminal of the protective device.)

It will be noted that a lightning arrester is not required under paragraph 810-20 when the lead-in conductor from antenna to entrance of building is protected by a continuous shield which is permanently and effectively grounded. Such requirement would, therefore, be met by proper grounding of the outer shield of the regular coaxial cable. Installation men should be particularly cautioned to comply with paragraph 810-18 and to refrain from the use of insulators or cable clips installed on or in buildings by telephone or lighting companies.

BOOSTERS

Where the signal obtained from the antenna is insufficient to provide a suitable picture, boosters are often employed. As their name implies, boosters are nothing more than RF amplifiers placed between the antenna and the TV receiver. The additional amplification provided by the booster raises the signal strength to the point where it is sufficient to drive the TV receiver.

There are many types of boosters available. Some are tuned to a single channel; others provide amplification for a few adjacent channels. Some provide all-channel VHF amplification and others are designed to cover a portion of all of the UHF channels.

Two types of mountings are employed for boosters. Some are fixed-tuned and are mounted on the mast near the antenna. These may be for single or all-channel (VHF) operation. Some antennas incorporate boosters as part of their design. Such boosters may use tubes or transistors. In either case, power must be supplied to the unit, either via the lead-in or separate leads.

Tunable boosters are usually housed in a wood or plastic cabinet and placed on top of the TV receiver. Then, when the TV receiver is switched to select a given channel, the booster is also set to the same channel.

The actual design depends upon the application intended for the particular unit. Some employ a single tube, while others have many. Of course, the more elaborate the design, the more gain obtained. Because of the wide variations, a booster can be obtained to fit almost any conceivable application.

MASTER ANTENNA SYSTEM

The primary purpose of a master antenna system is to provide individual antenna outlets to two or more locations. For example, hotels, motels and apartment buildings often use a single antenna system to supply the TV signal to all tenants. In addition, two or more TV receivers are often used in single-family dwellings.

Installing separate antennas for each TV receiver not only creates a maze of antennas on the roof, but also would be very expensive. All TV receivers cannot be connected to a single lead-in because of interaction between sets, and one antenna will not provide sufficient signal to drive all the TV

receivers in some buildings. Therefore, some means must be provided for connecting the receivers.

In another application of the master antenna system, a whole town may be supplied. Called a community-antenna system, such systems are employed in remote areas where satisfactory reception cannot be obtained otherwise. The antenna is located on a high tower or nearby mountain. Separate antennas are usually employed for each available channel. The signals are amplified and sent to the various subscribers' houses via a transmission line. Other amplifiers may be located at various points along the line.

There are presently three types of master-antenna installations being employed in multiple dwellings. They are:

1. Divider-network system.

2. Distribution-amplifier system.

3. Separate antenna system.

Divider-Network Antenna System—This system operates from a high-gain antenna able to provide sufficient signal strength for connection to a considerable number of receivers. Since no amplifiers are used and no power is required, a multiple antenna system of this type is low in maintenance and first cost.

Multi-set couplers are often employed in houses where it is desired to operate more than one receiver. They can also be used for operating a TV set and an FM receiver from the same antenna. The schematic for a typical divider-network, four-set coupler is shown in Fig. 20.

Distribution Amplifiers—Where several receivers must be connected to an antenna, the set couplers described previously may not supply sufficient signal. For example, hotels, motels, and apartment buildings often require several outlets. In installations such as this, some amplification must

also be provided. This amplification is provided by *distribution amplifiers.*

Essentially, a distribution amplifier is a booster with multiple outlets. The antenna is connected to the distribution amplifier, and the TV receivers are connected to the outlets. In elaborate systems, divider networks may be employed in each leg to provide more outlets. Still more
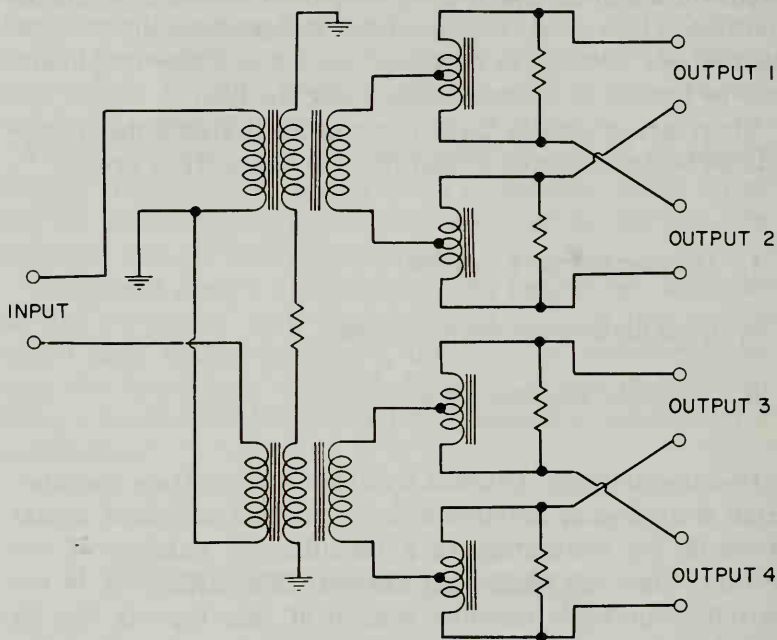
Fig. 20. Schematic of a four-set coupler.

distribution-amplifier systems may be inserted in the line to provide still more outlets.

Separate Antenna System—This system (Fig. 21) differs from the foregoing multiple-antenna systems, mainly in that a separate antenna is provided for each individual channel to be received. A group of pretuned amplifiers, one for each channel, is supplied to provide interference free signals to each receiver outlet.

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In addition individual resistance pads at the input of each channel amplifier are provided to enable the antenna technician to compensate for varying signal levels in any location.

In an installation of this type, it is important to separate the different channel antennas by a distance of 10 feet or more, to prevent any mutual coupling between them which may form a distorted picture. Coaxial cables are used to

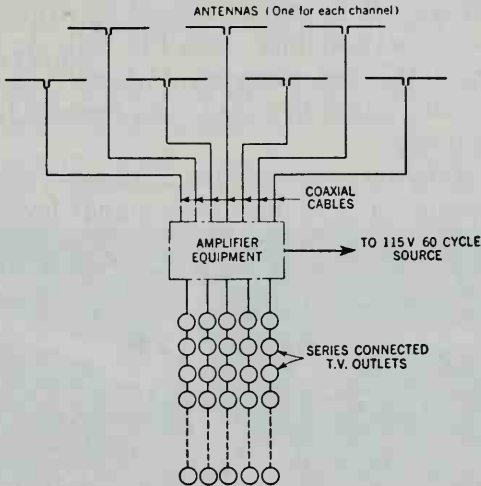Fig. 21. Schematic of a multiple-outlet system with separate antenna for each channel.

connect the antennas to the amplifiers in order to prevent noise pickup, and to match the input impedance of the amplifiers.

TROUBLESHOOTING MATV SYSTEMS

It is not always necessary to go through an entire troubleshooting procedure to pinpoint MATV troubles. A knowledge of what is probable in system malfunction can often

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provide helpful shortcuts. The most common causes of trouble symptoms in MATV systems are as follows:

AC Hum—Hum interference appears as one or two stationary or rolling dark bars on the picture-tube screen. The technician should check with a portable TV receiver to make sure that the hum isn't originating from a defective filter or circuit fault in the tenant's receiver. Then, if it is found that the hum is originating in the MATV system, it is most likely to be caused by a defective filter in the MATV amplifier.

Picture Rolling—When this trouble symptom appears on one channel only, it is usually caused by sync compression in a single-channel amplifier. (See Fig. 22). As an amplifier ages, tuning shifts can cause an AGC shift to produce increaed gain, and cause overload. The remedy is to troubleshoot the amplifier.

Cross Modulation in Broadband Systems—When this malfunction occurs, suspect first that signal levels may have
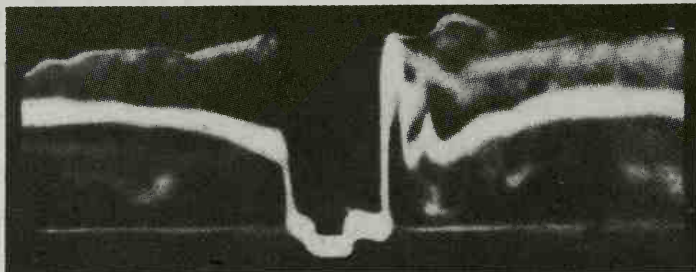
(A) Sync tip partially compressed.
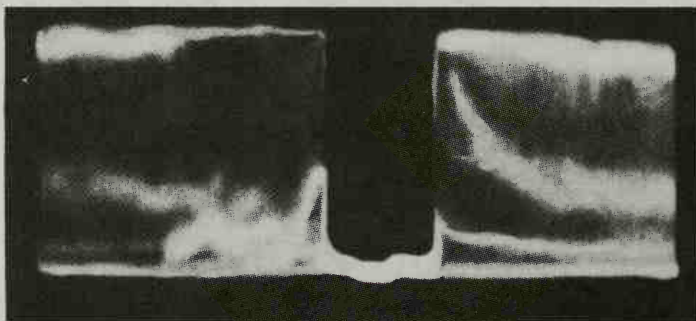
(B) Sync tip completely compressed.

Fig. 22. Sync-tip compression, owing to nonlinear amplification.

been set correctly in the past, but the maintenance man or some tenant may have changed the amplifier gain setting.

Ghosts—Sometimes a tenant will attempt to compensate for receiver deterioration by taking more signal out of the MATV system. For example, a tenant might short-circuit the isolation arrangement in the tap-off unit. Although increased signal is obtained, the resulting impedance mismatch often causes ghosts along the trunk line. In some cases, ghosts occur because a tenant has extended the line, and added some more outlets. Since few tenants understand the principles of impedance matching, ghosts are usually produced as a result.

Snow—If snow is observed throughout the entire MATV system, the amplifier is immediately suspect. On the other hand, snow in a particular branch run is often caused by water entering a splitter or a tap-off unit. However, snow can also be caused by anything from a new building structure to a defective cable, a faulty coax connector, or a deteriorated TV receiver.

SUMMARY

The actual selection of the type of antenna to be installed will depend on many factors. The first step in any antenna installation is an on-the-spot survey of the location. Look over the house to note type of construction, such as brick, stone, frame, etc., and the type of roof. The distance from the transmitting antenna is also an important factor.

Another important decision that must be made in the initial installation is, how to support the antenna. Again one of the primary factors in determining the selection is the distance from the transmitting antenna. In areas where the signal is strong any installation can be used. In fringe areas, tall towers are usually necessary.

Guy wires must be attached to practically every antenna installation to support the mast or tower. The only exceptions are self-supporting steel towers which are set deep in

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concrete, or eave and roof installations which extend only a few feet above the roof. In general, separate guy-wire systems should be attached for each 10-feet in height for masts.

Most television receivers have a 300-ohm input circuit which must be connected to a 300-ohm antenna system. Failure to observe proper impedance match between antenna and receiver will result in undesirable effects of noise and interference. Where interference may be picked up by the antenna lead-in itself, shielded coaxial cable may be used. Since coaxial cable is normally not available with a 300-ohm impedance, impedance-matching transformers should be used.

REVIEW QUESTIONS

1. What should be the first step to consider when planning an outside antenna system?
2. What determines the type of antenna to use?
3. What determines the type of antenna mast?
4. Can one outside antenna serve more than one TV receiver? If so, how?
5. When should guy-wires be used?
6. What is the purpose of the lightning arrester?
7. What is the master antenna system (MATV)?

Television Interference

After all the necessary adjustments have been made, the picture may have certain defects altogether different from those described in Chapter 4.

A multitude of patterns may be superimposed upon the normal picture. These patterns are produced by man-made disturbances usually termed interference. As an illustration, when two receivers are operated directly from the same antenna, it may happen that mutual interference occurs, as shown in Fig. 1. This type of interference is caused by front-end radiation, and the reception on both receivers will usually be substantially normal on certain channels. On other channels, it can happen that receiver A interfers with receiver B, while on still other channels, receiver B interferes with receiver A. The cure for this trouble is to use a two-set coupler that provides ample isolation between the receivers.

As evidenced in radio-broadcast reception, interference is recognized by a burst of noise or continuous background noise. In television reception, interference is evidenced by a burst of light upon the picture screen, momentary "tear out" of the picture, formation of various patterns on the screen, or small spots of light in the picture. Fig. 2 shows the appearance of "snow" on a picture-tube screen.

Since television receivers are designed to operate at much higher frequencies than broadcast-band radio receivers, the sources of interference are not the same for the two types of receivers. A television receiver is almost immune to
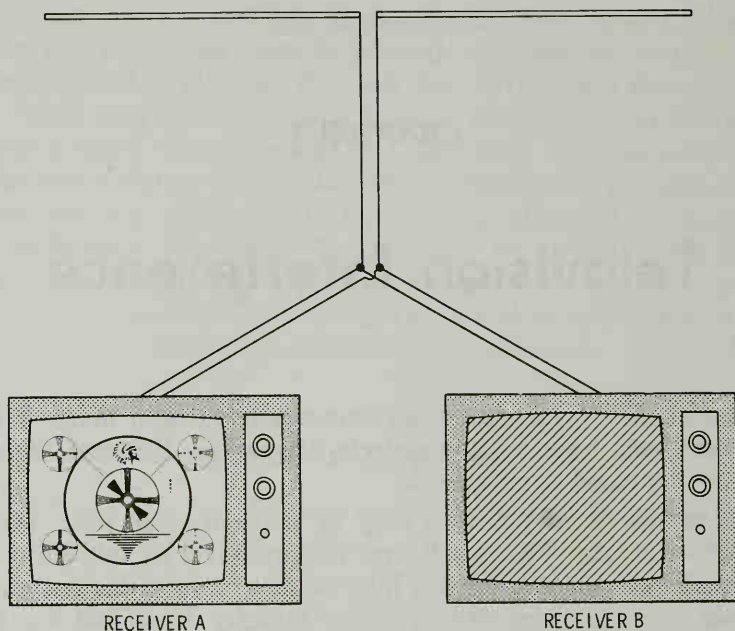
RECEIVER A   RECEIVER B

Fig. 1. Operating two receivers directly from the same antenna can result in mutual interference.

weather-produced interference, whereas this type of interference is most common in radio reception.

Some forms of interference are easily identified by an analysis of the interference pattern formed on the screen. After they are identified, corrective measures can be applied to eliminate them. Other types of interference, however, are not so easily identified, and, in some cases, there is no known corrective measure.

It is of paramount importance, therefore, that every service technician be thoroughly acquainted with the various forms of interference affecting television reception and know how to identify each type. Fig. 3 illustrates the appearance of 60-Hertz hum bar in the picture.

Proper identification may mean success or failure in correcting the trouble because if there is no clue as to what is causing a particular type of interference, no corrective measure can be applied to it.
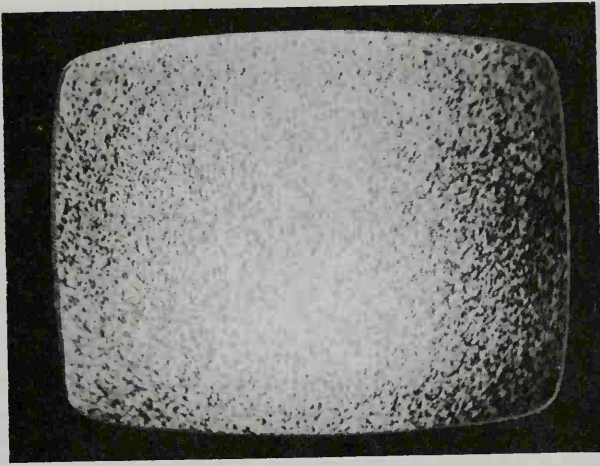
Fig. 2. Snow pattern on picture-tube screen.

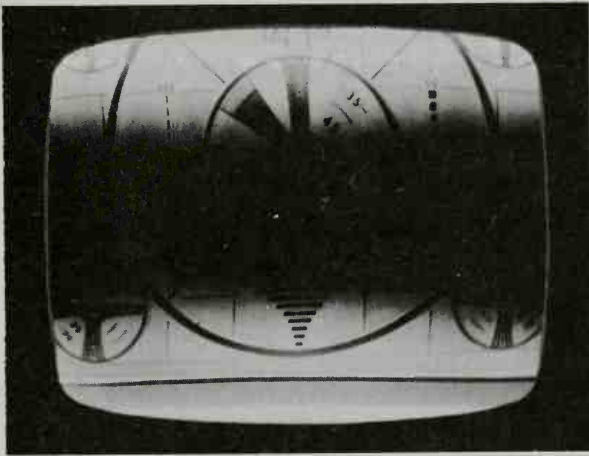Fig. 3. Appearance of 60-Hertz hum bar in the picture.

To anticipate subsequent discussion, it will be observed that interference may be either external or internal. In other words, if one receiver is interfered with by another receiver, the source of interference is external. On the other hand, a snow pattern exemplifies internal interference—receiver circuit noise is the source of the snow in most cases. Again,

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if a 60-Hz hum bar appears in the picture, the source of the interference is usually internal. Another example is shown in Fig. 4. Barkhausen oscillation produces the vertical black line at the left of the screen. The source of this type of interference is in the horizontal-output stage of the receiver.

COMMON TYPES OF INTERFERENCE

Television receivers are greatly affected by man-made noise arising from various types of electrical apparatus. Some types of interference frequently encountered by television service technicians follow. They are not necessarily listed in order of their importance or frequency of occurrence. They are:

1. Ignition or spark interference.

2. Diathermy.

3. Germicidal-lamp radiation.

4. 4.5 MHz sound-beat pattern.

5. Police, amateur, and other stations.

6. Two or more nonsynchronized TV carriers on same channel.

7. FM transmitter heterodyning with local oscillator in receiver.

8. Radiation from the local oscillator in a neighboring FM or TV receiver.

9. Oscillation in video IF amplifier.

10. Barkhausen oscillation from the horizontal-deflection generator.
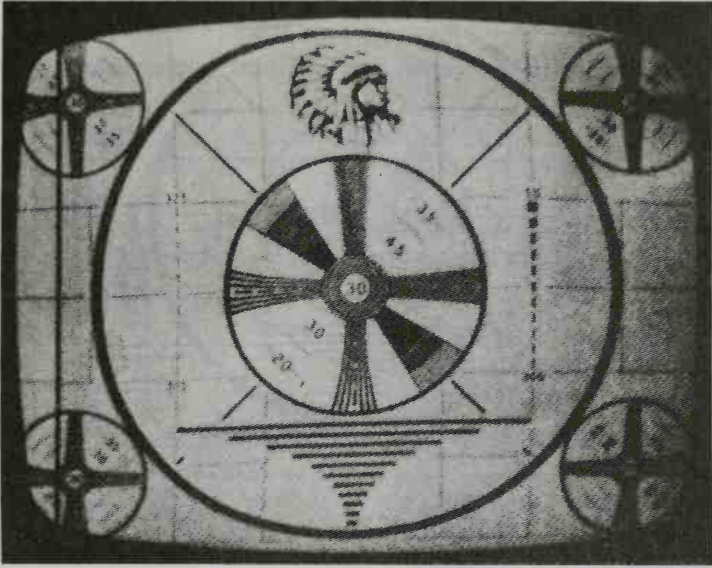
Fig. 4. An example of Barkhausen oscillation.

11. Reflections or ghosts.

IGNITION INTERFERENCE

Ignition interference from trucks, automobiles, and aircraft may be identified by streaks and splashes on the picture. The ignition system of trucks will produce the most intense interference pattern. It usually consists of a series of broken horizontal dark lines as shown in Fig. 5, the number or spacing of which depends on the frequency of the offending spark.

Aircraft in the vicinity may also produce interference which is usually identified by a temporarily fluctuating picture, usually lasting only a few seconds. Since the noise from the aircraft is usually heard at the time the fluctuation of the picture occurs, identification of this type of interference is comparatively easy.

Fig. 5. Test pattern showing effect of auto-ignition interference.

Interference of this same type can occur from high-voltage and corona discharge in the high-voltage supply of the receiver, as well as in high-tension lines near the receiver location. In addition, electric motors, doorbells, buzzers, and sign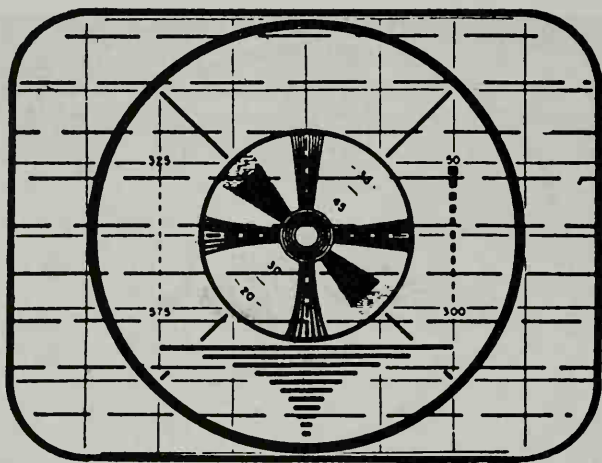aling systems such as teletype machines usually generate an interference pattern similar to that made by ignition systems.

Corrective Measures—At the outset it should be emphasized that there is no clear-cut method whereby all interference problems due to ignition or other causes may be solved. About the only corrective measure with respect to ignition interference is to ascertain that a good antenna is used, that is, one which will result in the best possible pickup of the signal.

At the time of installation, checks should be made to determine the type of interference, if any, which is present at the particular location.

The antenna should then be located as far as possible from the suspected source of interference. Thus, for example, if the receiver is located near a heavily traveled arterial highway or street intersection, the antenna should always

be installed as far from the traffic as possible, and the twin-lead twisted once every five feet.

After this has been accomplished, an effort should be made to eliminate the remainder of the interference by manipulating the antenna. Perhaps increasing the antenna height by several feet would assist in eliminating the interference.

In locations plagued by interference, shielded twin-conductor cable, or coaxial transmission lines should be used.

Fig. 6. Appearance of RF interference in the picture.
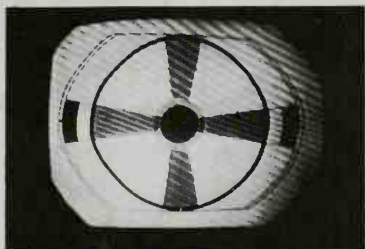
The use of the shield will prevent most of the noise pulses from reaching the transmission line. For a shielded line to be completely effective, however, the shield must be properly grounded.

In cases where a coaxial cable (single conductor) is used, be sure proper impedance-matching devices are used. Otherwise, the problems produced by the mismatch may be greater than those of the original problem. Fig. 6 illustrates the appearance of RF interference in the picture.

DIATHERMY

Diathermy interference (Fig. 7) is caused by unshielded medical diathermy machines and X-ray equipment. It manifests itself in a herringbone pattern or one of two dark bars moving slowly up and down the picture. If the disturbance is extremely strong, the interference pattern will remain stationary while the picture floats in the background.
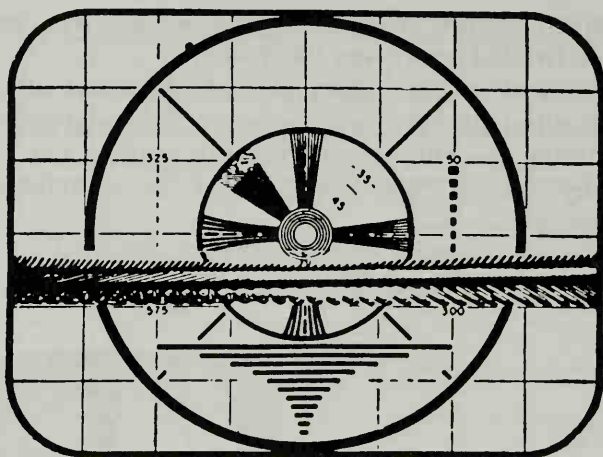
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Fig. 7. Test-pattern showing effect of diathermy interference.

Many diathermy machines consist of oscillators using raw 60-Hertz AC on the plates. Distribution of the pattern relative to picture height is usually similar to a 60-Hertz hum bar due to the strong AC ripple in the signal. This "strip" or bar pattern will vary in position relative to the top and bottom of the picture, depending on the phase relation between the power lines supplying the diathermy machine and the vertical scanning frequency of the receiver.

Sometimes if this bar happens to be so phased as to occur near the vertical-blanking interval, it will show up as two split narrow "strips" one at the top of the picture and one at the bottom. The fine-line pattern within the "strip" will vary in spacing depending on the frequency of the diathermy oscillator; and, as these oscillators are not crystal controlled, the fine-line pattern will usually vary, assuming various positions between horizontal and vertical.

Corrective Measures—In the case of diathermy interference, corrective measures are practically nonexistent, since the signal from a diathermy "transmitter" behaves very much the same as television signals, that is, it is picked up by the receiver antenna.

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It is evident that the only permanent remedy against television interference of this sort is to incorporate preventive measures at the source, that is, by proper shielding and filtering of the diathermy machines, by shielding of the room or rooms in which they are operated, or both. Fortunately, modern diathermy machines operate on different frequencies than previously and do not produce the interference previously encountered.

GERMICIDAL-LAMP RADIATION

Fortunately interference from germicidal lamps is not of frequent occurrence. Lamps of these types are used most frequently in hospitals, butcher-shop meat counters, refrigeration locker plants, etc., to kill bacteria.

The interference pattern from germicidal lamps is very similar to that originating in diathermy equipment.

Corrective Measures—In interference cases of this sort, the only corrective measure which has been found effective is to replace the offending lamp with a new one. It seems that after a period of time certain lamps increase in efficiency to the extent of killing both the bacteria and television reception.

4.5-MHZ SOUND-BEAT PATTERN

This type of interference may be recognized by a stationary very fine herringbone pattern independent of sound modulation and extending over the whole picture. This is caused by the intercarrier sound-IF signal being coupled to the picture tube and heterodyning between the sound and video IF carriers.Fig. 8 illustrates a 4.5-MHz beat pattern.

Corrective Measures—Most receivers employ a fairly high-Q trap, tuned to 4.5 MHz, and installed either in series with the cathode-ray tube grid or in the video-amplifier chain somewhere between the point of sound takeoff and
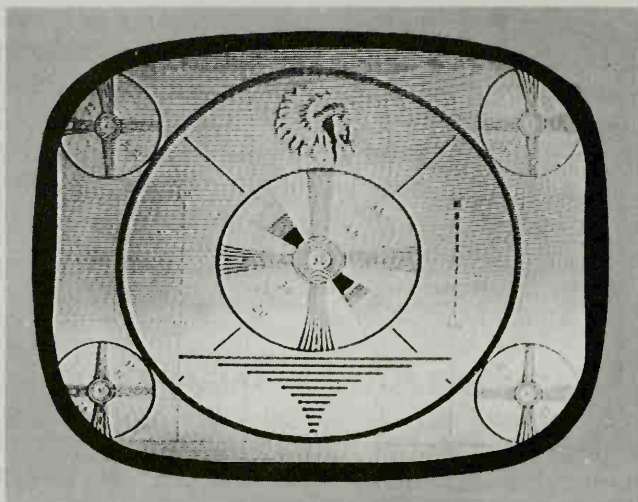
Fig. 8. A 4.5MHz beat pattern.

the cathode-ray tube grid. This trap may need readjustment. In extreme cases, it may be necessary to install an additional trap at some other point in the circuit.

POLICE, AMATEUR, AND OTHER STATIONS

Interference from these sources usually emanate from transmitters being located in close proximity to television receivers resulting in a high signal level being fed into the receiver circuit. The fact should not be overlooked that most video amplifiers will amplify to approximately 4 MHz and consequently will readily amplify the signal from a broadcast station if the receiver happens to be in the high-signal area very close to the transmitter. Fig. 9 illustrates a 28-MHz beat produced by an amateur transmitter.

Corrective Measures—Corrective measures consist of judicious use of shielding of the affected parts of the receiver and the use of traps tuned to the frequency of the offending transmitter.

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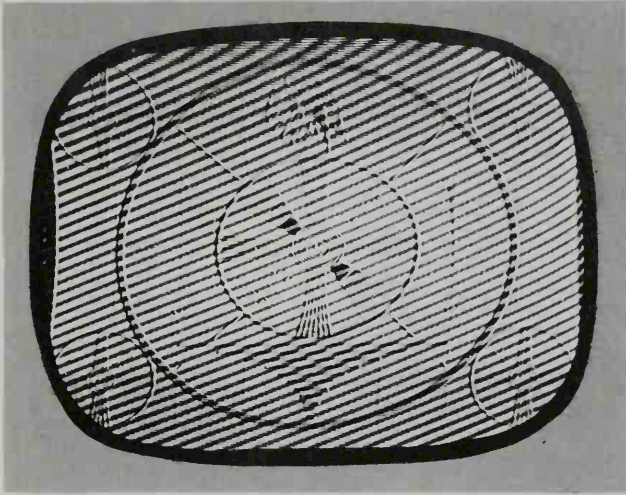
Fig. 9. A 28-MHz beat produced by an amateur transmitter.

TWO OR MORE NONSYNCHRONIZED TV CARRIERS ON SAME CHANNEL

Interference of this type usually affects reception in fringe areas where the television receiver is located equidistant between two or more stations. Sometimes the signals from the different stations are almost equal in strength and as a consequence the receiver cannot discriminate between the transmitters. This type of interference is called the "windshield-wiper" picture symptom, if the receiver locks on one TV signal, while the blanking bars of the other signal "wipe" across the screen. Or, the interference is called the "venetian-blind" picture symptom, if the beat frequency between the two signals produces visible horizontal bars on the screen. Fig. 10 shows the appearance of windshield-wiper interference, and Fig. 11 illustrates the venetian-blind picture symptom.

Corrective Measures.—The only possible solution to interference problems of this sort is to employ a highly di-

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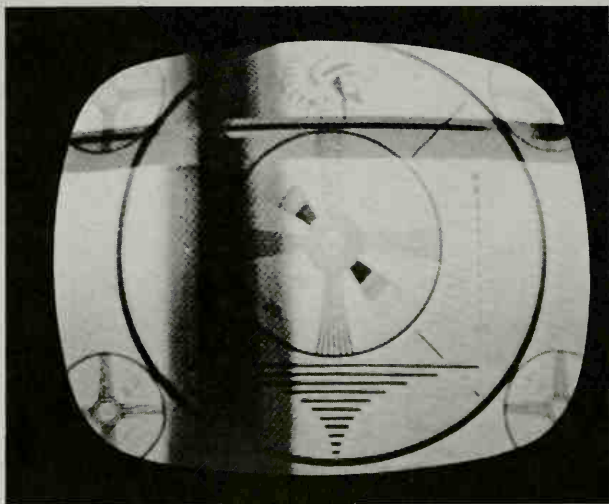
Fig. 10. The appearance of the windshield-wiper effect.

rectional antenna, and mount it in a rotating mechanism so that it can be precisely aimed at the desired station.

FM TRANSMITTER HETERODYNING WITH LOCAL OSCILLATOR

The heterodyning of an FM transmitter with the local oscillator and the resultant beat coming in on the lower television channels is another cause of interference. Receivers in most of the larger television areas where powerful FM transmitters are located are usually affected by this type of interference.

It is usually recognized on the screen as an ever-changing pattern of parallel lines sometimes assuming a herringbone characteristic. The pattern will usually change continuously, except when the FM transmitter modulation is off; and the movement of the lines in the pattern will not bear any relation to the accompanying television sound. The number

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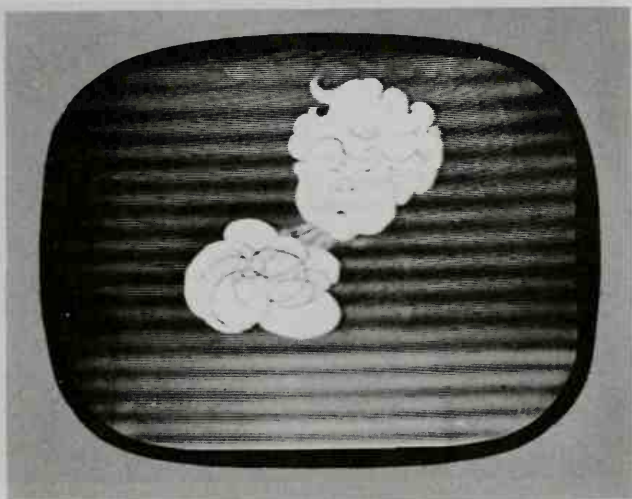
Fig. 11. Example of cochannel interference.

of lines or bars varies according to the modulation of the interfering transmitter.

Corrective Measures—An effective corrective measure in this case consists of fairly high-Q traps at the antenna input to the RF unit of the receiver and tuned to the interfering FM signal.

RADIATION FROM THE LOCAL OSCILLATOR IN A NEIGHBORING FM OR TV RECEIVER

Interference emanating from a source of this type will vary, depending upon what channel the interfering receiver happens to be tuned to and on the nature of the signal it heterodynes with.

It will usually result in a fine herringbone pattern covering the entire picture, although sometimes it will take the form of a ghost picture which seems to float around in the background of a picture tuned in on one of the TV channels.

This trouble is commonly encountered when two or more TV receivers are operated from the same antenna without

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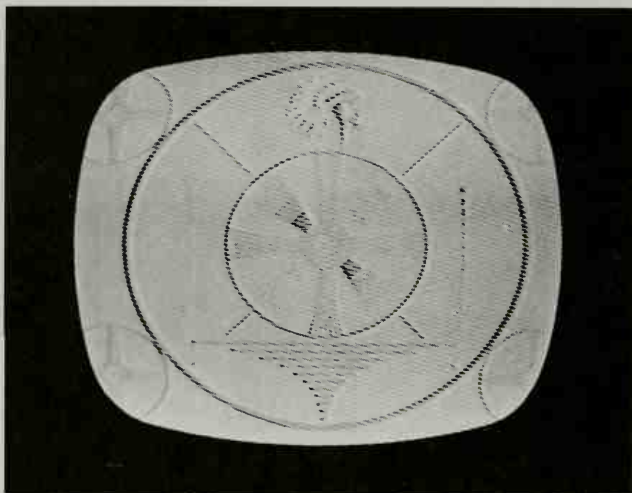
Fig. 12. Effect of local-oscillator interference from another TV receiver.

isolating couplers connected into the lead-in system. It also occurs when individual antennas are used with two or more receivers, and the lead-ins are run close together. Even if the lead-ins are well separated, interference sometimes occurs when the antennas are mounted too closely together on the same roof. Fig. 12 illustrates the appearance of local-oscillator interference.

Corrective Measures—The solution is to install a wave trap tuned to the interfering frequency.

OSCILLATION IN VIDEO-IF AMPLIFIER

A trouble of this nature will usually manifest itself as a pattern of lines that are approximately three thirty-seconds of an inch apart. This pattern will be noticed on all channels and usually only when the contrast control is advanced near or past the midpoint of its travel. This trouble can usually be traced to an open screen bypass capacitor in one of the video-IF amplifier stages or, in receivers employing stagger-tuned IF's, oscillation can result if several of the stages are peaked too closely together.

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Note that the picture symptom can vary considerably, depending on the amount of IF feedback, and the incoming signal level. For example, strong signal may be reproduced at low contrast and with ringing of vertical lines with cer-

Fig. 13. Distorted reproduction with wedge ringing at about 2.5MHz.
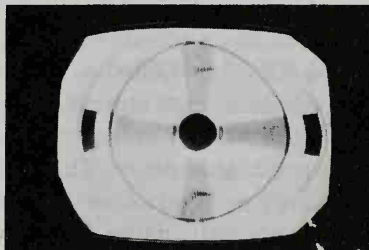
tain spacing, as shown in Fig. 13. At a reduced signal level, a negative or partially-negative picture may appear. Again, at a slow signal level, the screen becomes blank, due to increased IF feedback at low AGC voltages.

BARKHAUSEN OSCILLATION

Barkhausen interference originates in the receiver's horizontal-deflection circuit. It will show up as a dark vertical line or a series of lines at either side of the picture.

If a pattern such as the one described is noticed, a permanent magnet held close to the outside of the horizontal-output tube will have a noticeable effect on the pattern.

Barkhausen effect is a type of high-frequency oscillation that takes place within the electron stream in the tube. The frequency is determined by the distance between the elements and by the velocity of the electrons. It is independent of external tuning circuits.

Corrective Measures—Replacement of the horizontal deflection tube will usually clear this type of interference. Attaching an ion-trap magnet to the outside of the horizontal output tube will also usually eliminate Barkhausen oscillations.

REFLECTIONS OR GHOSTS

Perhaps one of the most prevalent forms of interference is that due to reflections of the signal, generally termed ghosts (Fig. 14). Since there are numerous forms of this type of interference, they will be treated according to their appearance on the screen.

The Trailing Ghost—This is probably the most common type of ghost and is usually due to a reflection from a building, hill, or other structure that reflects the television signal from the transmitter. This reflected signal or "echo," which is usually weaker than the direct signal, arrives at the receiving antenna later than the direct signal, and the ghost or echo will appear on the right hand, or trailing edge, of the picture.

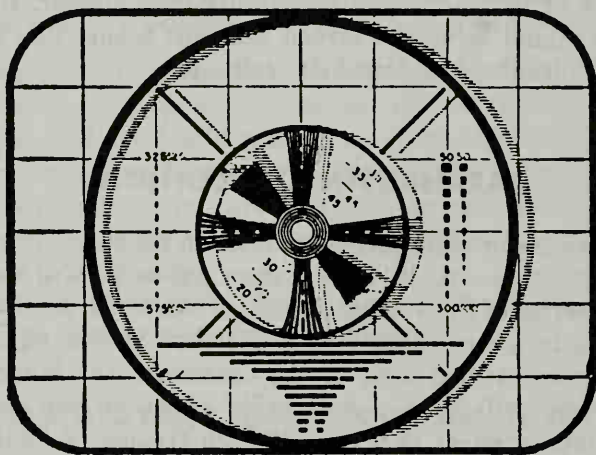Fig. 14. Test pattern showing effect of multiple images or ghosts.

Sometimes there are locations where several reflected signals from different buildings or structures reach the receiver resulting in several ghost images in the picture. These are called multiple ghosts. Ghost images can be positive or negative, depending on the relative phase of the direct and reflected signal. The relative phase depends on the location

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of the antenna. If the antenna is located some distance from the transmitter, the relative phase changes, and the direct and reflected signals either aid or oppose, producing a positive or negative ghost. A negative ghost is one where the image is reversed; that is, the white portions are black and the black portions are white.

Corrective Measures—Where the reflected signal is arriving at the receiver from the rear, a reflector on the antenna will be helpful because it will minimize the rear pickup of the antenna to some extent. If the reflected signal is arriving at the receiver from one side, it can be minimized by orienting the antenna for least pickup in this direction even though the direct signal is reduced slightly. In either case, a highly directional antenna is desirable. Under some conditions it may be advantageous to orient the directional antenna for maximum pickup of a strong reflected signal and minimum pickup of the direct signal.

Source Ghost.—When the reflected signal arrives at the receiving antenna from the same general direction, relative to the direct signal from the transmitter, and the angular difference between the two signal paths is very small, it is impossible to differentiate between the two signals resulting in a ghost image, which is called a source ghost. So far there is no known corrective measure for reflections of this type.

Fluttering Ghost.—Fluttering ghosts due to reflections from aircraft flying in the vicinity of the receiver are sometimes observed. The changing phase of the reflected and the direct signal arriving at the receiver as the plane moves along, results in the two signals alternately aiding and opposing each other, to produce a fluttering in the picture brilliance and also a flutter in the ghost image. The rate of flutter depends on the position, height, speed, and direction of the plane and changes as the plane progresses in flight. This type of interference is largely overcome by the horizontal-AFC circuit in the television receiver.

Leading Ghosts.—Leading ghosts differ from trailing ghosts in this respect. With a trailing ghost, the ghost image is to the right of the direct pickup picture, while with a

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leading ghost, the ghost image appears to the left of the direct pickup picture. This type of ghost appears under the following conditions:

1. With the receiver located relatively close to the transmitter, considerable signal pickup occurs in the RF or mixer circuits of the receiver with a long run of transmission line from antenna to receiver. The signal that is picked up directly in the RF or mixer circuit appears ahead of, or to the left of the picture from the antenna signal, which is delayed in traveling down the long transmission line. In cases of this type, the signal picked up directly by the receiver will usually be affected by the movement of persons about the room or near the television receiver; and as the signal usually is reflected by objects in the room or nearby structures, multiple ghosts will usually be evident.

2. If a reflected signal is stronger than the direct signal, it will appear as the principal image and the direct signal will appear as a ghost image. Since the direct signal does not travel as far to reach the antenna it will be reproduced to the left of the reflected signal producing the predominate picture.

Corrective Measures—If RF or mixer pickup is the cause, it can be corrected by reducing the direct pickup in the receiver by shielding the RF and mixer circuits and possibly the entire chassis. By disconnecting the antenna from the receiver without disturbing the contrast-control setting, it can be determined how much signal the antenna is actually contributing to the picture.

If it is found that multiple ghost images appear and that the antenna contributes very little or nothing to the picture, the pickup from the antenna system should be increased or a defect in the RF amplifier stage of the receiver may be the cause. It should be obvious that if the RF amplifier stage of a receiver was inoperative, disconnecting the an-

tenna would not affect the picture because the reproduced image, or images as the case may be, would be due to direct signal pickup in the mixer circuit.

If the reflected signal is stronger than the direct signal, the ghost can be eliminated by employing a more directional antenna and carefully orienting the antenna.

Tunable Ghost—These are ghost that vary in number and intensity as the fine tuning control of the receiver is adjusted and are usually caused by incorrect alignment, or possibly regeneration, in the video IF stages.

Transmission-Line Ghost—When the transmission line is not correctly terminated at the receiver, a portion of the signal is reflected at the receiver and travels back up the line to the antenna. If the antenna does not correctly terminate the line, a portion of this signal is reflected back and travels down the line to the receiver again, where it produces a trailing ghost.

With a normal length of transmission line, the reflected signal takes very little time in traveling up and down the line, so it is only slightly delayed and does not appear as a separate ghost. It merges with the original picture signal and affects the picture quality by effectively widening the vertical lines so that they appear fuzzy. Only with long runs of transmission line, will the reflected signal appear as a distinct and separate ghost.

Corrective Measures—Proper matching of impedance between the antenna and transmission line and the transmission line and receiver input will reduce or eliminate the problem.

INTERFERENCE TRAPS

In the foregoing discussion of television interference and its corrective measures, mention was made of the insertion of wave traps. These are used in certain instances of interference, but should be resorted to only where all other corrective measures have failed to remedy the trouble.

Wave Traps—Various types of interference emanating

from FM and amateur transmitters and some commercial or police communication systems in addition to radiation from local oscillators of neighboring television receivers, can effectively be suppressed by the insertion of wave traps.

Interference conditions of the foregoing type can be corrected by lowering the amount of signal input to the receiver at the frequency which causes the interference. A wave trap may be inserted in series with the antenna or it may be built into the receiver as a permanent feature.

A wave trap consists of an LC circuit of fairly high Q which will resonate at the frequency it is desired to attenuate. They are often series resonant and inserted in one or both conductors of the transmission line and tuned to the interfering frequency. Fig. 15 is the circuit diagram of a commonly used wave trap. The two traps are wired so that one is in each leg of the antenna circuit; and thus they will not materially unbalance the antenna circuit.
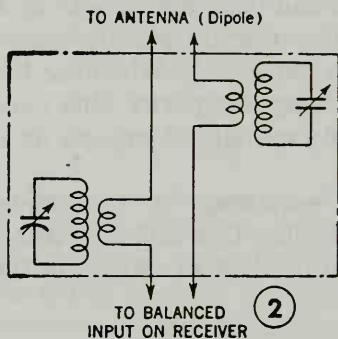

Fig. 15. Schematic of a typical wave-trap.

Suppression circuits can also take the form of a parallel-resonant circuit which is inserted in the grid-coupling system between the RF and mixer stages; therefore it curbs the mixing action which produces the interference in the IF system.

To construct an effective wave trap, it is first necessary to calculate the frequency of the interfering signal and con-

struct or purchase a trap which can be inserted and tuned until the interference disappears. Booster amplifiers, because of their added selectivity, are also employed to suppress signal interference. It is for this reason that booster amplifiers are sometimes employed in strong signal areas. The signal is reduced later with a resistance pad.

Impulse-Noise suppression—Impulse noise originating in electrical appliances such as electric cash registers, office equipment, electrical shavers, etc., can best be suppressed at the source. This is commonly accomplished by the insertion of a small capacitor shunted across the AC line at the input to the device.

For complete noise suppression from large industrial equipment, electrical signs, etc., there are several types of filters on the market consisting of series-inductor and shunt-capacitor combinations which prevent RF energy from feeding back to the power line and then radiating or feeding directly into the television or radio receiver.

Because of the tendency of numerous noises to enter the television receiver via the power line, a filter inserted between outlet and receiver will, in a great many instances, effectively suppress noises emanating from home appliances or industrial equipment operating on the same power line.

It is a well known fact that neon signs are notorious offenders in television and radio reception disturbances. The flasher device is nothing but a set of switches and should therefore be treated similarly to that employed to silence other industrial equipment.

Another source of disturbance in neon signs is arcing between connections particularly in the electrode housing or between cable ends. Again interference may be caused by flickering tubing, an overloaded transformer, faulty insulation, corona discharges between tubing and ground, loose connections, ungrounded transformer case, a broken conductor inside the insulation, etc.

When reception interference has been found to be caused by a neon sign, each of these trouble sources should be investigated. As a general rule, however, it has been found

that the employment of filter units across switch contacts and also across the primary winding of the transformer will remedy the trouble.

It has also been found effective to install a high-frequency choke properly insulated between the letters of the sign. When filters are installed, it should be remembered that the components employed must be able to withstand the potentials and the current which must flow through them.

Perhaps the most important consideration in areas plagued by interference and noise is the choice of antenna and its proper orientation. These considerations, however, have been fully covered elsewhere and need no further elaboration.

SUMMARY

Television receivers are operated at a much higher frequency than radio receivers and the source of interference are not the same. A television receiver is almost immune to weather-produced interference, whereas radio reception is generally effected by such actions.

Many forms of interference can be identified when viewed on the screen. After they are identified, corrective measures can be applied to eliminate most of them. Some types of interference are not so easily identified, and, in some cases, there are no known corrective measures. Man-made noise arising from various types of electrical apparatus, such as, electric motors and automobile ignition noise, can be partially eliminated by using the proper antenna and proper placement.

Interference conditions can generally be corrected by lowering the amount of signal input to the receiver at the frequency which causes the interference. A wave trap may be inserted in series with the antenna or it may be built into the receiver as a permanent feature.

REVIEW QUESTIONS

1. Why are antenna transmission lines twisted?
2. What effect do aircraft have on the TV picture?
3. What are the most common types of TV interference?
4. Explain the Barkhausen oscillator.
5. What is the purpose of the wave trap?
6. What causes local-oscillator interference from one TV receiver to another?
7. What causes the venetian-blind effect?

CHAPTER 8

RF Tuners

The RF tuner (or front-end, as it is sometimes called) is the first section in the television receiver to receive and act upon the composite video signal. There are many types of tuners, but all perform the same basic functions. The block diagram of a television tuner is given in **Fig. 1.**
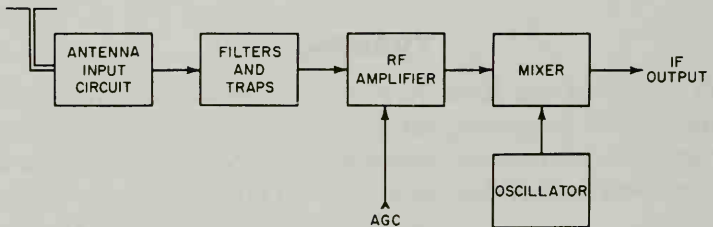

Fig. 1. Block diagram of a television RF tuner.

As indicated by the block diagram, the tuner in a tele- vision receiver essentially performs the same functions as the RF amplifier and converter sections of a conven- tional broadcast or short-wave radio. In a television receiver, however, there are many problems not encoun- tered in broadcast radio. These problems complicate the design of the television receiver RF tuner. These problems are:

1. The broad bandwidth of the television channel. Proper television reception requires that a band of

frequencies *6 megahertz* wide be accepted and amplified. For broadcast radio, the required bandwidth is only a few *kilohertz*.

2. The frequency allocations of TV Channels (54-88MHz, 174-216MHz, and 470-890MHz) necessitate special coupling circuits. Component and lead placement are critical. Fig. 2 shows a typical VHF frequency response curve, and Fig. 3 shows the chief features of a sweep generator.

3. Input circuits must be properly matched to the impedance of the transmission line and antenna and provide the proper match between transmission-line impedance and the RF amplifier transistor input impedance.

4. Even though a wide-band response (6MHz) is desired, many other signals outside the bandwidth of the desired channel must be avoided. Such undesired signals are :

   (a) Adjacent-channel sound carrier.

   (b) Adjacent-channel video carrier.

   (c) Signals at the intermediate frequency which might be coupled through the RF system.

   (d) Signals from other television or FM stations.

   (e) Overloading of the RF amplifier by strong signals from any type of station.

5. The local-oscillator signal must be properly isolated from the antenna. This is one of the principal reasons that all television receivers employ RF amplifiers. If the oscillator signal was allowed in the antenna cir-
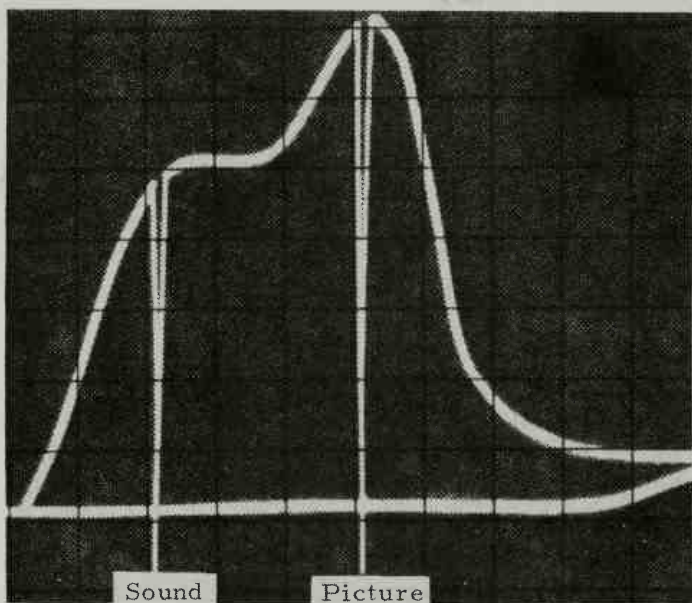
Fig. 2. An RF response curve with sound-carrier and picture-carrier frequencies
marked.

cuit, the antenna would function as a transmitter
and radiate the signal to all nearby television receiv-
ers, causing severe interference. The amount of
radiation permissible is regulated by the FCC. With-
out an RF amplifier, it is very difficult to suppress
oscillator radiation to permissible limits.

TYPES OF RF TUNERS

RF tuners can be classified in two different ways. The
type of RF amplifier (which is the principal circuit differ-
ence) can be used as a means of classification. The various
types of RF amplifier circuits will be discussed later. The
other method of classification is by the type of mechanical
means employed to accomplish channel selection.

Push buttons, continuous (variable inductance or variable
capacitance), wafer switch, turret, and disc tuners have

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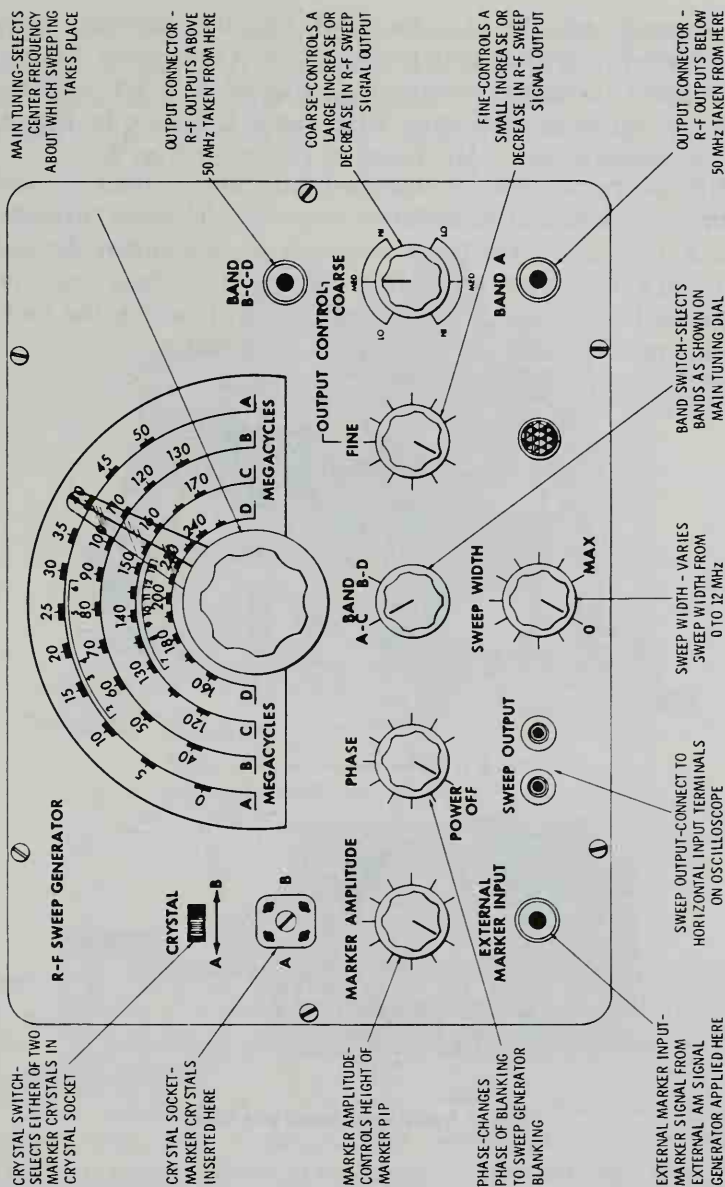
Courtesy Heath Co.

Fig. 3. A VHF sweep generator used to check frequency response curves.

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been employed. By far the most popular systems, however, are the switch and turret types. Continuous tuning, in modern television receivers, is limited to UHF application. A typical miniaturized VHF tuner is shown in Fig. 4, and a miniaturized UHF tuner is shown in Fig. 5.

RF tuners can also be classified into tube, transistor, and hybrid types. An all-transistor tuner is solid-state throughout. A typical hybrid tuner employs semiconductor devices in the RF, oscillator, and mixer stages, but utilizes a special UHF oscillator tube. These variations with which the technician must contend are explained subsequently.
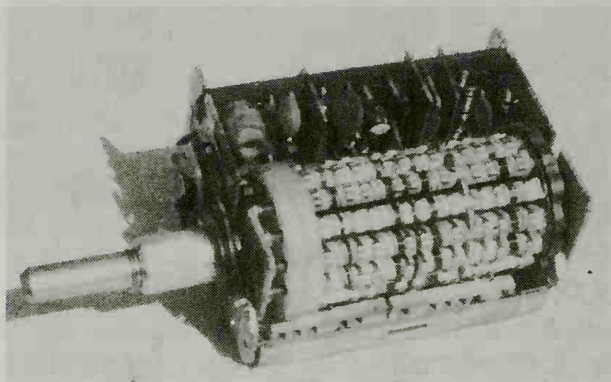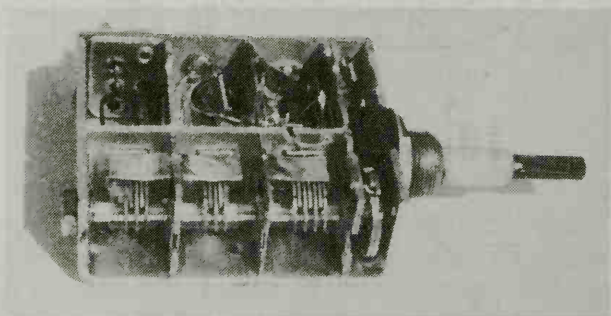

Fig. 4. A typical miniaturized VHF tuner.

Fig. 5. A typical miniaturized UHF tuner.

Turret Tuners—A typical tube type turret tuner is pictured in Fig. 6. The coils employed to tune the RF amplifier

input and output, mixer input, and oscillator input are mounted on the individual strips which form the drum. Each coil is connected to the silver-plated contacts on the outside of the strip. These strips then mate with a set of contacts
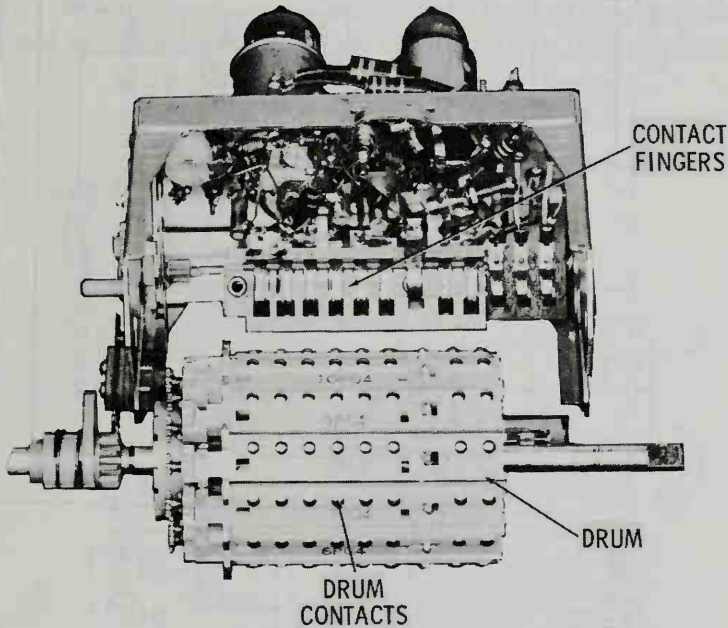

CONTACT
FINGERS

DRUM

DRUM
CONTACTS

Fig. 6. A turret-type tuner.

inside the tuner to complete the circuit. For each channel, a separate set of coils is included. As the channel selector shaft is rotated, a different set of coils is switched in for each channel.

Most tuners used in transistor TV receivers are of the turret type. Fig. 7 depicts the configuration for a VHF transistor tuner. Printed circuitry is often utilized, although metallic chassis construction is employed when optimum low-impedance ground returns are a design goal. A high-pass
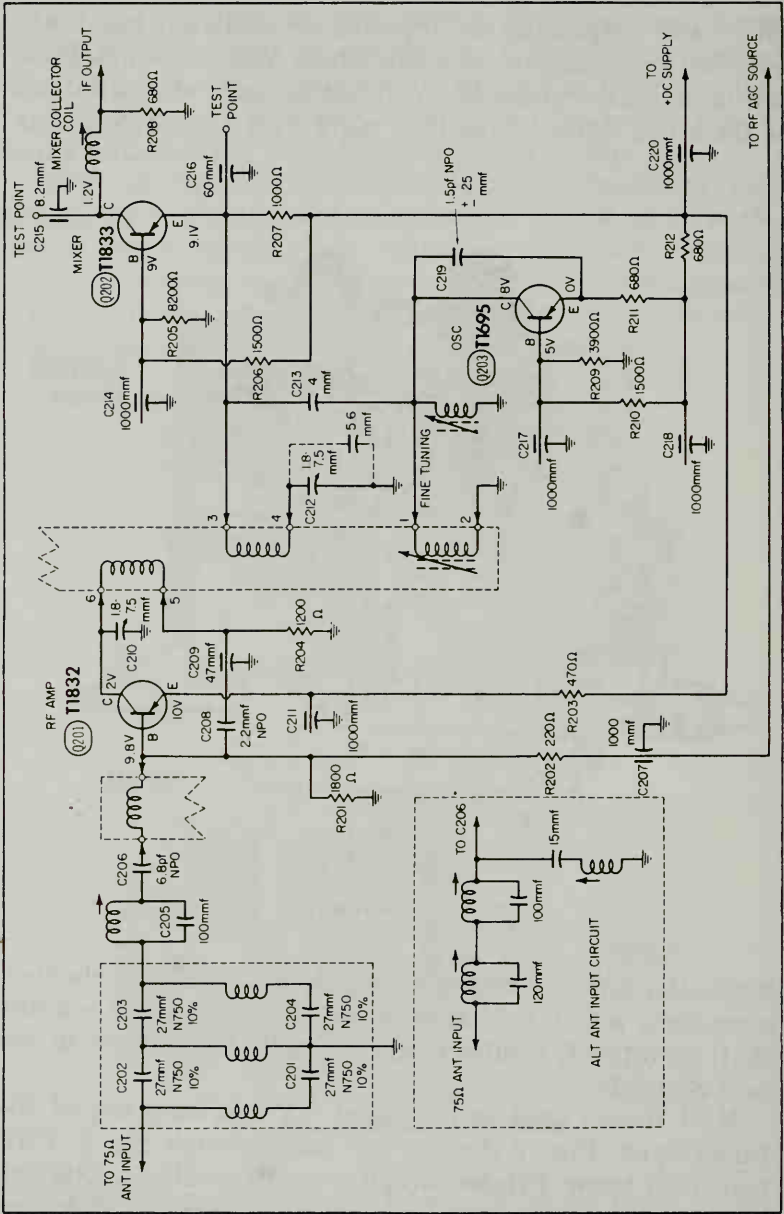
Fig. 7. Schematic of a typical turret-type transistor tuner.

filter and IF trap are connected in the antenna-input circuit in this example. An alternate interference-rejecting arrangement comprises three tunable traps, as shown in the inset.

Neutralization is accomplished by out-of-phase feedback via C208 in Fig. 7. Transistor Q201 operates at an average forward bias of 0.2 volt, subject to AGC variation. Since the mixer transistor operates with emitter and collector circuits tuned to different frequencies, neutralization is not required
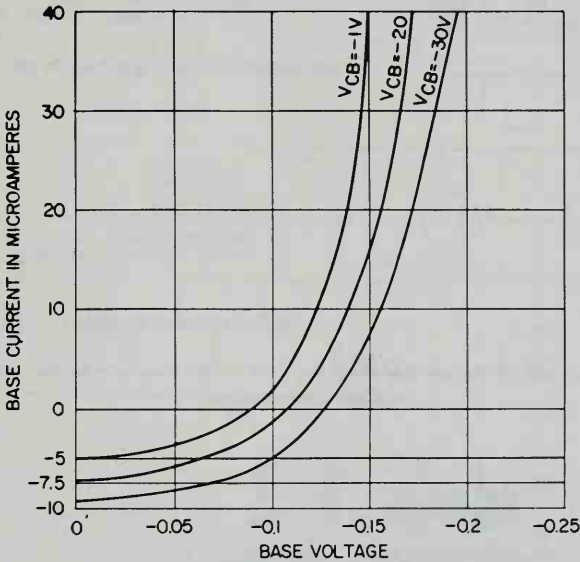

Fig. 8. Base family of characteristics.

in this stage. The mixer transistor operates at 0.1 volt forward bias, because a nonlinear characteristic is required for heterodyne mixer action. Fig. 8 shows how the emitter-base characteristic has maximum nonlinearity in the vicinity of 0.1 volt forward bias. Fig 9 lists the important characteristics of the three basic bipolar transistor configurations.

Wafer-Switch Tuners—Unlike the turret tuner, individual coils are not employed in wafer-switch tuners (Fig. 10). A series of coils are connected between the contacts on each
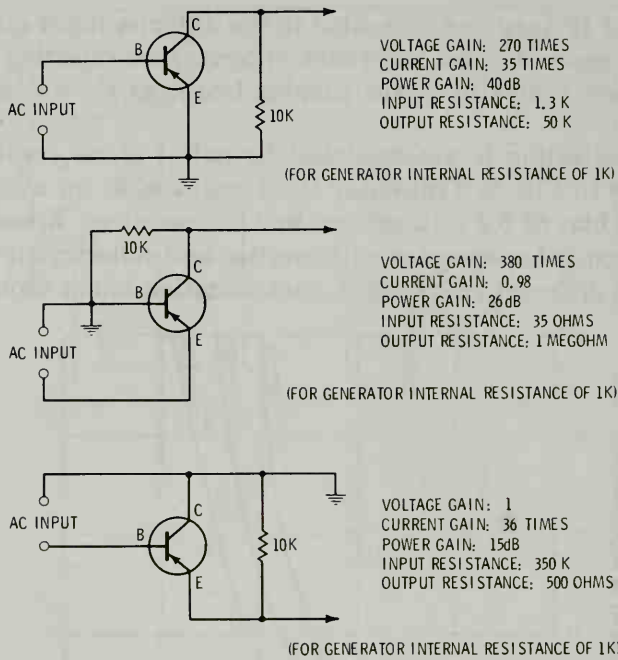
VOLTAGE GAIN: 270 TIMES
CURRENT GAIN: 35 TIMES
POWER GAIN: 40 dB
INPUT RESISTANCE: 1.3 K
OUTPUT RESISTANCE: 50 K

(FOR GENERATOR INTERNAL RESISTANCE OF 1K)

VOLTAGE GAIN: 380 TIMES
CURRENT GAIN: 0.98
POWER GAIN: 26 dB
INPUT RESISTANCE: 35 OHMS
OUTPUT RESISTANCE: 1 MEGOHM

(FOR GENERATOR INTERNAL RESISTANCE OF 1K)

VOLTAGE GAIN: 1
CURRENT GAIN: 36 TIMES
POWER GAIN: 15 dB
INPUT RESISTANCE: 350 K
OUTPUT RESISTANCE: 500 OHMS

(FOR GENERATOR INTERNAL RESISTANCE OF 1K)

Fig. 9. Comparison of typical characteristics of a triode transistor in the three basic amplifier configurations.
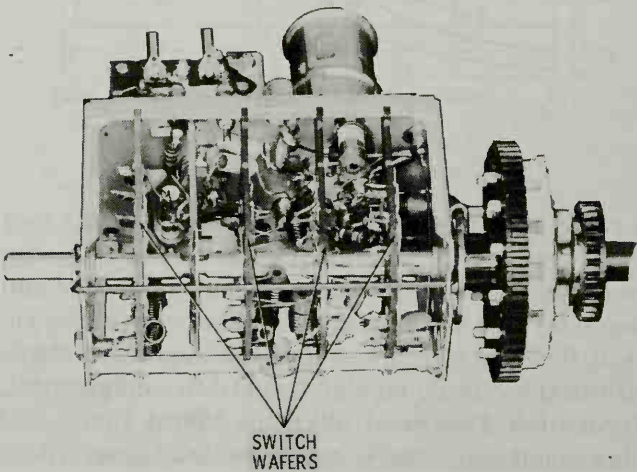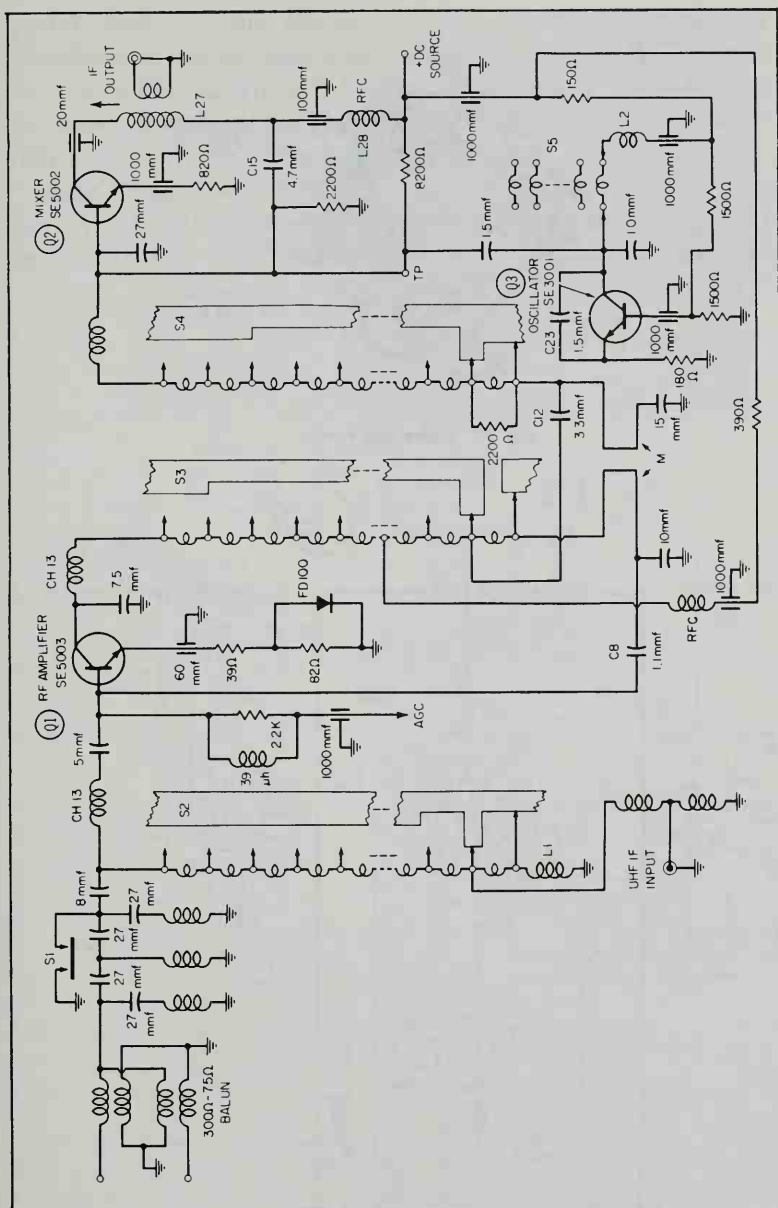

SWITCH
WAFERS

Fig. 10. A wafer-switch type tuner.

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Fig. 11. Schematic of a typical switch-type tuner.
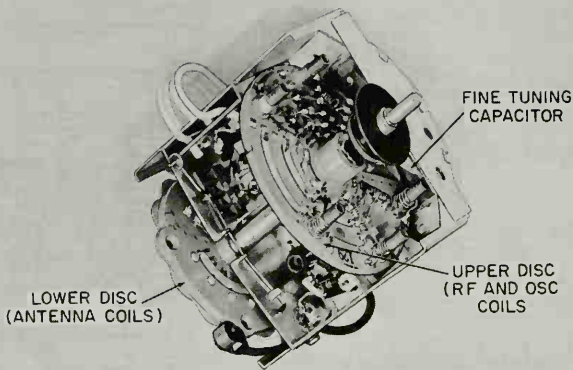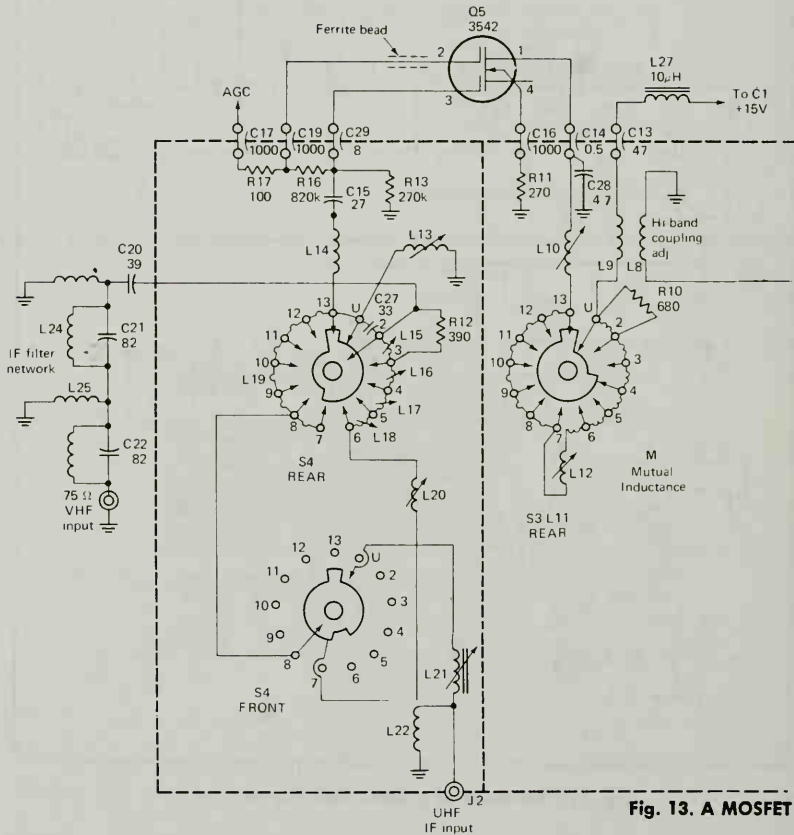
215

Fig. 12. A disc-type tuner.

Fig. 13. A MOSFET

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switch deck. As the channel-selector shaft is rotated, the inductances are incrementally added or subtracted to tune the desired band. Thus, this type of tuner is often called an incremental-inductance tuner. The configuration of a transistor wafer-switch tuner is illustrated in Fig. 11.

Disc Tuners—A disc tuner (Fig. 12) combines certain principles of both the turret- and switch-type tuners. Attached to the shaft inside the tuner are two large discs

Courtesy RCA Corp.

VHF tuner configuration.

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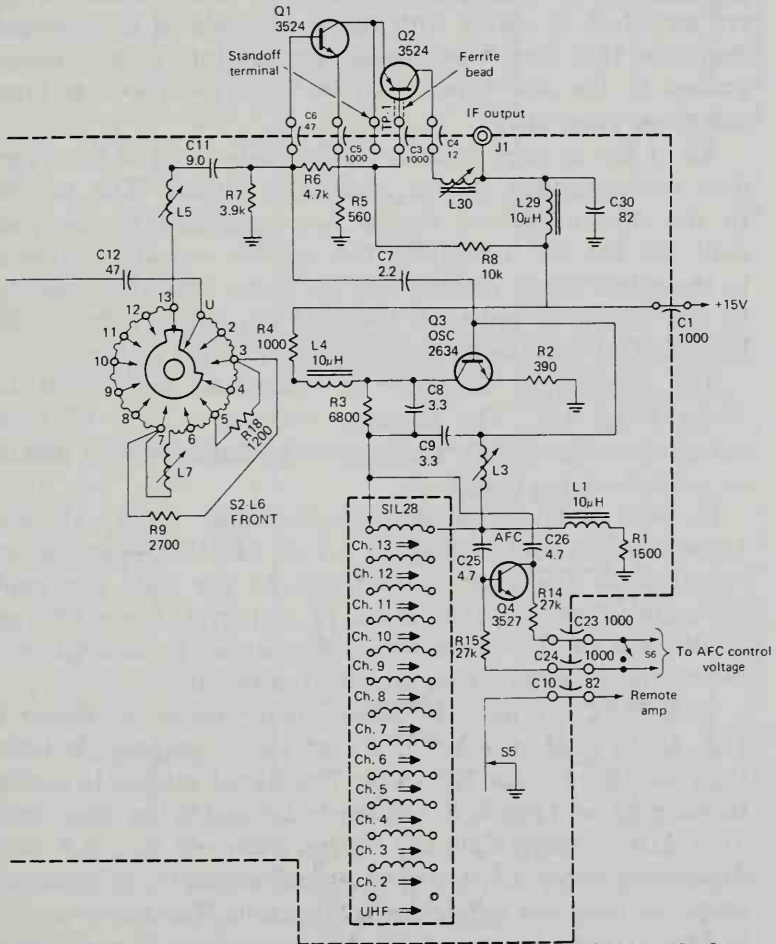
upon which the tuning inductors are arranged. The an-
tenna coils are on the rear disc. A detent mechanism re-
sembling that of the turret tuner is mounted on this disc.
Contact buttons and fingers, like those of the turret tuner,
connect the disc to the external circuitry.

An important difference between the turret and disc
tuners is that the disc tuner does not have a completely
separate set of coils for each channel. There are several
sets of basic coils plus incremental inductances which
are switched in series with the basic coils to tune certain
channels. However, the coils are broken into more separate
groups in the disc tuner than in the typical switch tuner
described previously.

All of the contact buttons on the under side of the upper
disc are arranged in six concentric circles. The buttons
in the innermost two circles are connected to the plate
coils for the RF amplifier, the middle two are connected
to the mixer input circuit, and the outer two are connected
to the oscillator coils. A 1.5-mmf capacitor connects the
low-band RF coils to the corresponding mixer coils.

The fine-tuning capacitor is located at the top of the
tuner (Fig. 12). The movable plate is a strip of metal
attached to the tuning shaft, and the fixed plate is printed
on a small wiring board.

In still smaller versions of the disc tuner, all coils
(antenna, RF, and oscillator) for all 12 VHF channels are
mounted on one disc. Connections to the coils are made
by spring contacts like those in a turret tuner. Proper
positioning of the wheel for each channel is assured by a
detent mechanism like the one in a turret tuner.

A MOSFET type VHF tuner configuration is shown in
Fig. 13. A dual-gate MOSFET of the N-channel depletion
type is utilized in the RF stage. The signal voltage is applied
to one gate, and the AGC voltage is applied to the other gate.
This AGC voltage normally varies from -5 to $+6.7$ volts,
depending upon the incoming signal strength. A dual-gate
amplifier does not require neutralization. The mixer section
in Fig. 13 uses a pair of bipolar transistors in a standard

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	COMMON SOURCE	COMMON GATE	COMMON DRAIN
N CHANNEL			
FEATURES	High voltage gain High input impedance Moderate output impedance Input and output out of phase	Moderate voltage gain Low input impedance Moderate output impedance Input and output in phase	No voltage gain Good current gain Very high input impedance Low output impedance Input and output in phase
P CHANNEL			

Fig. 14. Basic FET circuits.

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cascode circuit. Q1 operates in the CE mode, and drives Q2 which operates in the CB mode. The oscillator stage uses a bipolar transistor in a Colpitts circuit. Q4 functions as a varactor diode in an AFC circuit to keep the VHF oscillator from drifting off-frequency. The oscillator operates at 41.25 MHz above the sound-carrier frequency. Important characteristics of the basic FET amplifier configurations are listed in Fig. 14.

ANTENNA INPUT CIRCUITS

As mentioned previously, the primary purpose of the antenna input circuit is to match the impedance of the antenna to the input impedance of the RF amplifier. Normally a balun (for balanced-unbalanced) is used for impedance matching. In addition, most antenna input circuits also include trap circuits for removing unwanted frequencies from other sources such as amateur radio, commercial communications, and other sources.
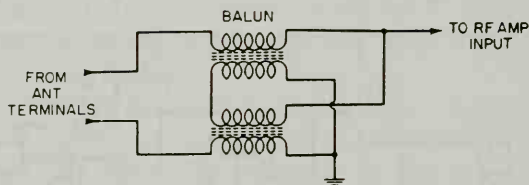

Fig. 15. A balun for matching a 300-ohm balanced antenna to a 300-ohm unbalanced input.

The circuit of a balun designed for matching a 300-ohm balanced antenna to an unbalanced input is given in Fig. 15. At first, the balun appears to be a transformer; however, it is actually two sets of parallel-tuned lines, similar to that obtained from ordinary twin-lead line, constructed in a lumped form to conserve space. They are constructed of extremely fine wire and wound on a coil form or on a ceramic core.

The balun coils are precisely tuned by length so that they are connected for the proper input and output impedances, minimum mismatch and maximum transfer of energy.

Another type of balun is illustrated in Fig. 16. This unit is designed for matching a 75-ohm antenna, such as the built-in monopole illustrated, to a 300-ohm balanced input.
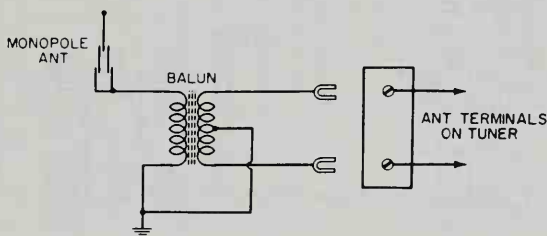

Fig. 16. A balun for matching a 75-ohm unbalanced antenna to a 300-ohm balanced input.

Usually various trap circuits are also included in the antenna input. Four examples of typical inputs are shown in Fig. 17. The ones in Figs. 17A and B are for matching balanced antennas to unbalanced tuner inputs, while the ones in Figs. 17C and D are for matching balanced antennas to balanced tuner inputs. Many other circuits are employed; however, all will resemble those in Fig. 17.

RF AMPLIFIER CIRCUITS

Unlike radio receivers where the RF amplifier stage is sometimes omitted, all modern television receivers employ an RF amplifier stage. As mentioned previously there are two reasons for incorporating an RF amplifier stage. First, the additional gain provided increases the sensitivity of the receiver. This is particularly important where distant stations, with resulting weak signals must
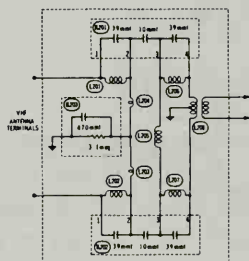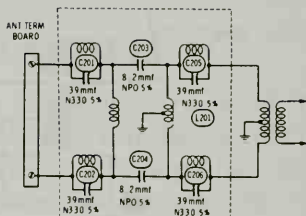
221
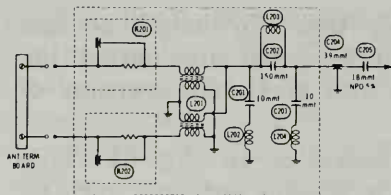
(A) Balanced to unbalanced.
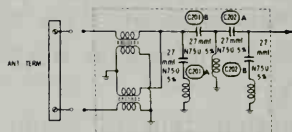
(B) Balanced to unbalanced.

(C) Balanced to balanced.

(D) Balanced to balanced.

Fig. 17. Typical antenna input circuits.

be received. The second reason is that the RF amplifier helps to isolate the oscillator stage from the antenna. Thus radiation of the oscillator signal from the antenna is reduced.

A widely used RF amplifier configuration is shown in Fig. 18. An unbypassed emitter resistor is used to optimize the signal-to-noise ratio and to reduce the possibility of cross-modulation. Capacitor C_N provides neutralization. Forward automatic gain control is used. In other words, as the incoming signal strength increases, the forward bias is increased on the transistor. In turn, the transistor approaches saturation, and its gain decreases. Forward AGC requires that the value of R3 be at least 1000 ohms, so that the collector voltage on the transistor decreases substantially as the forward bias is increased.

Transistors used in VHF amplifiers must have a suitably high alpha cutoff frequency. For example, the mesa tran-

sistor is often used, as shown in Fig. 19. The circuit depicted in Fig. 20 shows a typical configuration utilizing the mesa
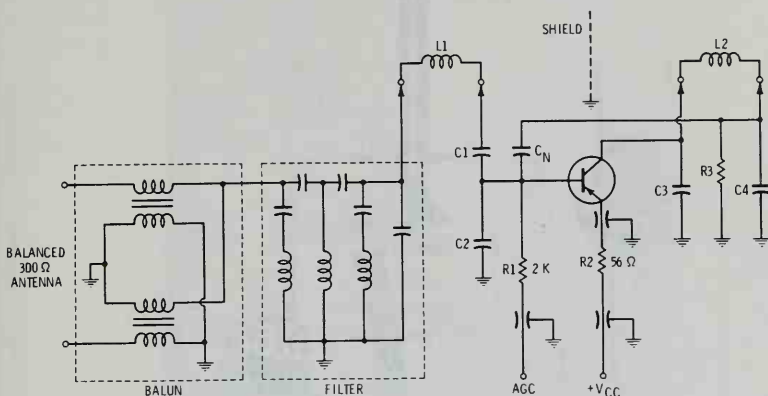

Fig. 18. A widely used RF amplifier configuration.

transistor. This type of transistor has a better noise figure, good gain, and is economical. Much of its merit is due to its low interelectrode capacitance. A typical mesa RF amplifier has a gain of 25 db and a noise figure of 7 db on channel 13, with a gain of 35 db and a noise figure of 5 db on channel 2. This is a slightly higher gain and a lower noise figure than found in RF amplifiers using other types of high-frequency transistors.

OSCILLATOR CIRCUITS

The purpose of the oscillator is to generate a signal 45.75MHz above the incoming signal (video) frequency. The incoming signal and the oscillator signal are then mixed to produce the correct IF difference signal.

A typical local-oscillator configuration is shown in Fig. 21. Since a common-base transistor amplifier is generally regenerative at VHF, this mode of operation is suitable for an oscillator arrangement. Positive feedback is provided via C10 and C11. The value of C7 determines the level of in-

223
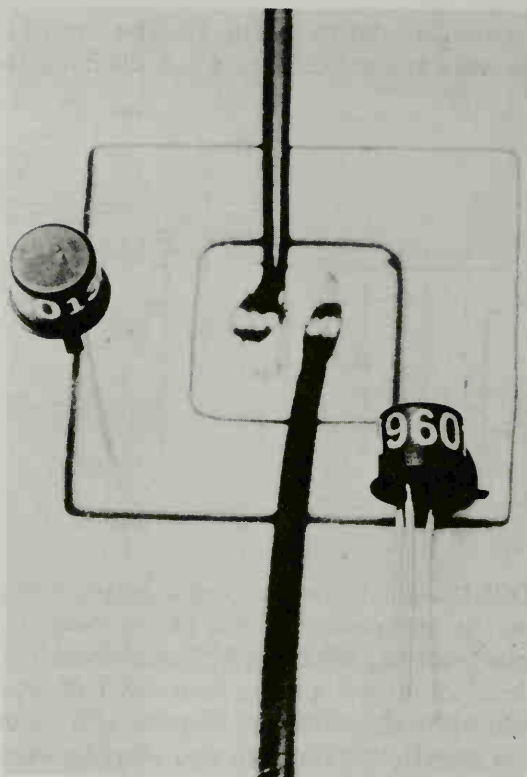
Fig. 19. A typical mesa transistor.

jection voltage to the mixer. About 0.15 volt of oscillator signal into the mixer provides maximum gain. The fine-tuning slug has a range of greater than ±1.5 MHz. Use of slug tuning in each oscillator coil permits the use of a preset fine-tuning arrangement.

Quite a few RF tuners include an automatic fine-tuning system. It comprises an error sensor and a control device. A typical error sensor consists of a discriminator circuit, as shown in Fig. 22. A sample of the IF signal is fed to the discriminator, which has a frequency response as shown in Fig. 23. One of the discriminator diodes is forward-biased and the other is reverse-biased. This provides a push-push
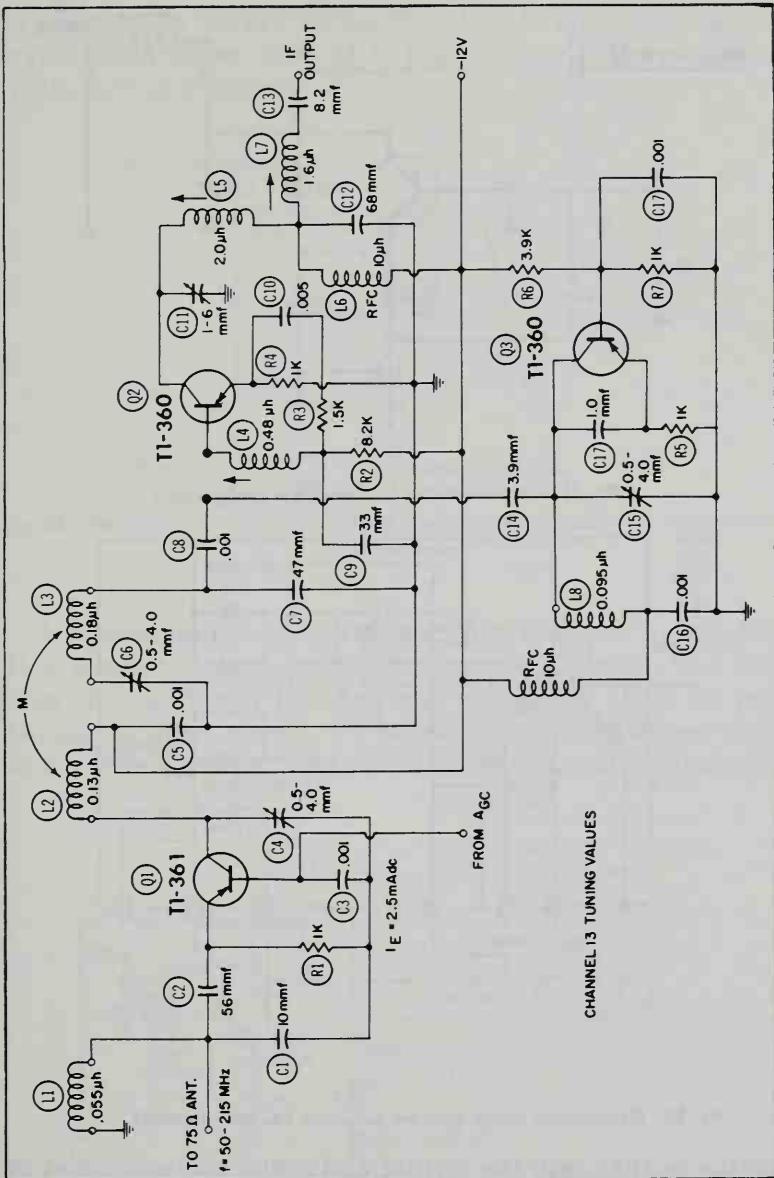
Courtesy Motorola Inc.

Fig. 20. TV tuner with mesa transistors.

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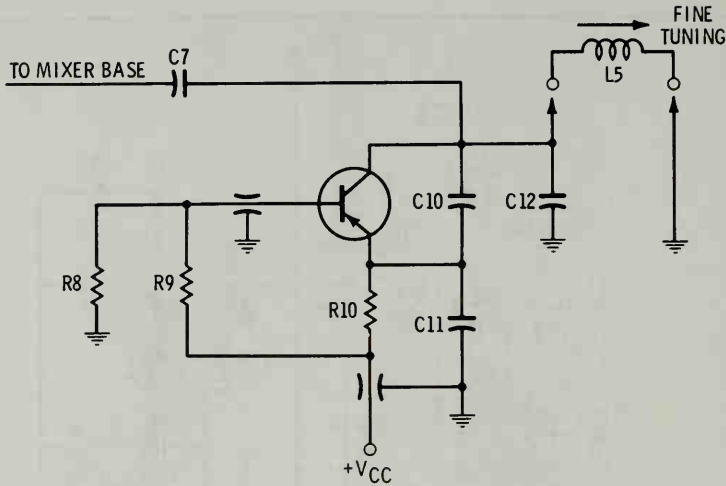
Fig. 21. A representative local-oscillator configuration.
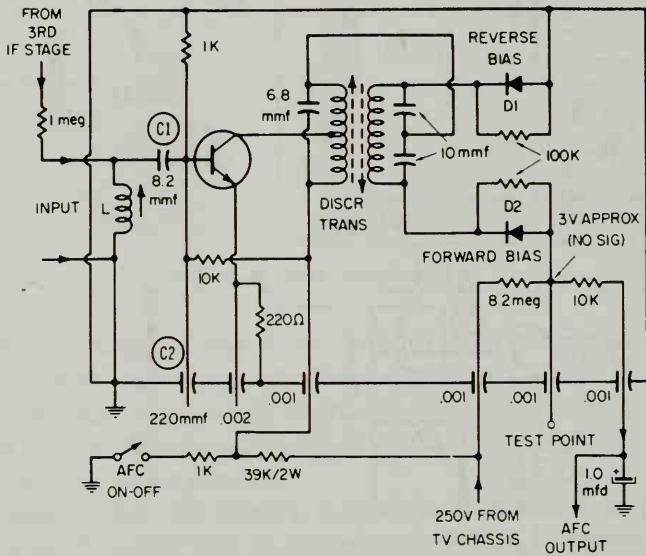
Fig. 22. Discriminator circuit used for automatic fine-tuning control.

action so that both the picture and sound carriers assist in producing a corrective output voltage. This corrective voltage is applied to a varactor diode, as shown in Fig. 24. As

the correction voltage varies from 1 to 8 volts, the varactor capacitance varies from 15 to 6 pf, to return the oscillator to its correct frequency.
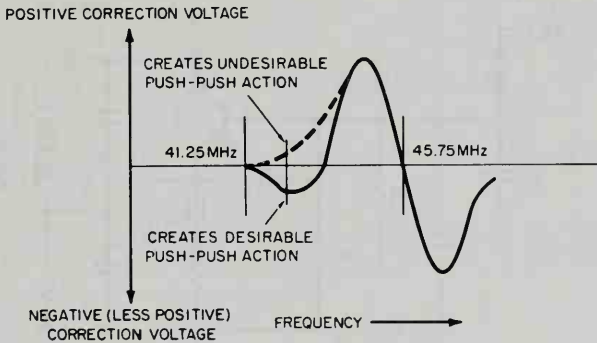
Fig. 23. The discriminator diodes in Fig. 2 2 are biased to modify the conventional response curve.

A representative mixer configuration is shown in Fig. 25. It is similar to an amplifier arrangement, except that the base and emitter of the transistor are at the same DC potential. In other words, the base-emitter junction operates as a rectifying diode. Thereby, heterodyne action is obtained.
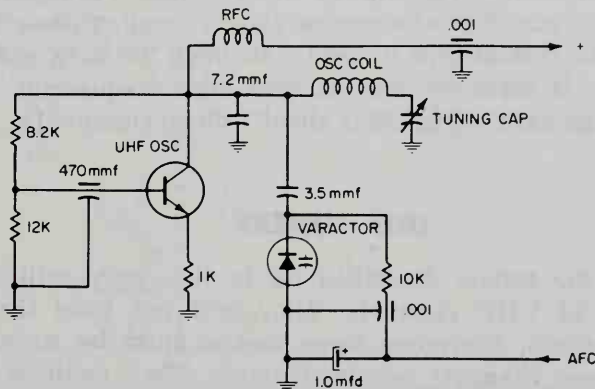
Fig. 24. A varactor operates as a variable capacitor.

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Neutralization if provided by C_N to ensure operating stability. A 50-ohm output impedance is provided, to match a 50-ohm coaxial cable to the IF strip. The DC collector voltage is chosen at a value that provides maximum stage gain.
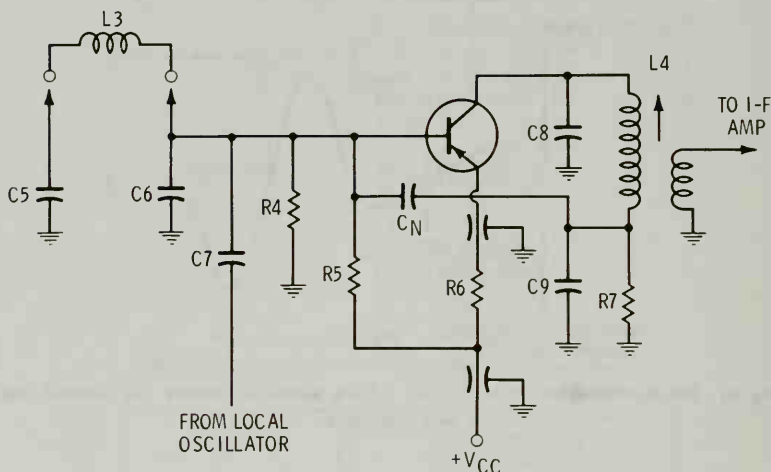
Fig. 25. A representative mixer configuration.

Fig. 26 shows the circuit for a typical transistor mixer stage, with the associated RF and oscillator sections. Tetrode transistors are seen in this example. A tetrode transistor is also called a double-base transistor. The basic arrangement is shown in Fig. 27. Bias voltage V_{BB} constricts the base current flow at a comparatively small cross-section. In turn, the transit time is shorter through the base, and the transistor is more efficient at very-high frequencies. The mixer stage gain in Fig. 26 is about 7 db on channel 13.

UHF TUNERS

All of the tuners described up to this point will only tune the 12 VHF channels. They will not tune the 70 UHF channels, therefore some means must be provided before these channels can be received. Two methods are employed: two tuners, one for VHF and one for UHF

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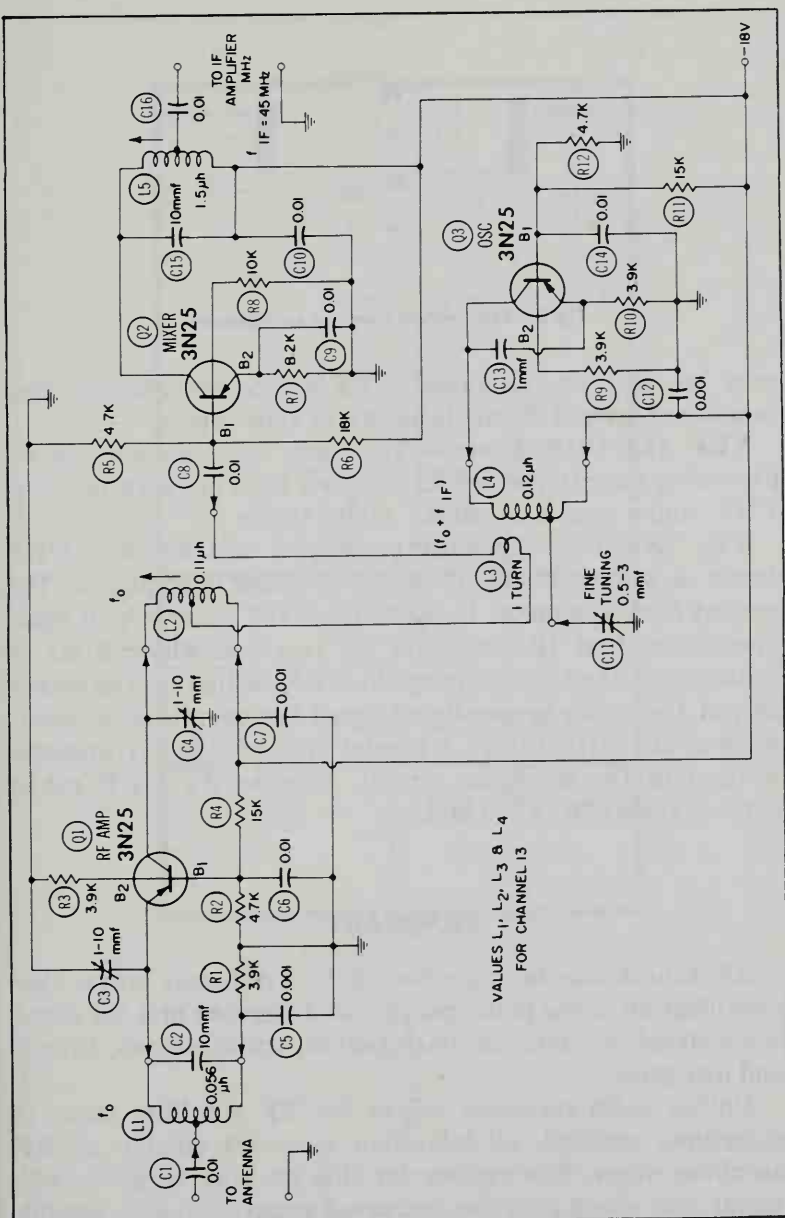
Fig. 26. VHF mixer with RF amplifier and oscillator.

229
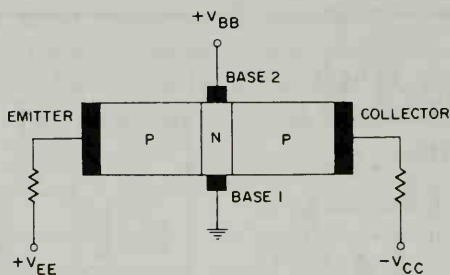
Fig. 27. Basic tetrode transistor arrangement.

may be used, or individual UHF strips may be inserted in place of unused channels on turret-type tuners.

VHF and UHF Tuners—The most common method of providing reception of all 82 channels is to use a 13-position VHF tuner and a separate UHF tuner.

Fig. 28 shows the arrangement of a transistor UHF tuner. A semiconductor diode mixer stage is employed. The output from the mixer is fed to the VHF tuner which operates as the first IF section in the receiver. About 5 ma is drawn from the DC supply by the UHF oscillator. The mixer output frequency is usually adjusted for operation on channel 6 of the VHF tuner. A special type of silicon transistor is used in the oscillator circuit, because the UHF range extends from 470 to 890 MHz.

SUMMARY

RF tuners can be classified in two different ways. One classification is the principal circuit difference and the other is construction; such as, push button, wafer switch, turret, and disc type.

Unlike radio receivers where the RF amplifier stage is sometimes omitted, all television receivers employ an RF amplifier stage. The reason for this is, first, to give additional gain which provides increased sensitivity, and, second, to help isolate the oscillator stage from the antenna.
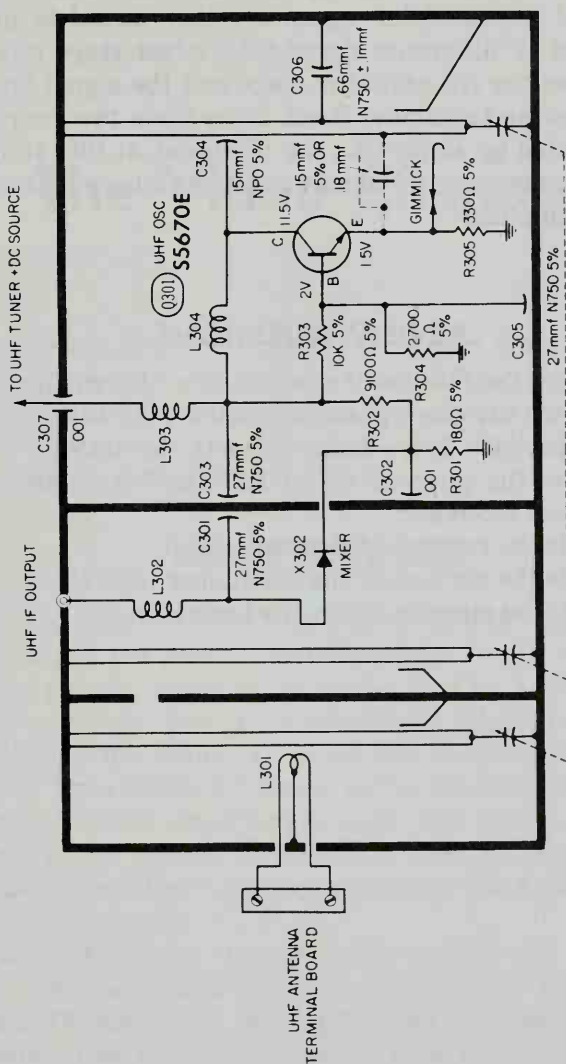
Fig. 28. Schematic of a typical UHF tuner.

The purpose of the oscillator is to generate a signal 45.75-MHz above the incoming signal frequency. The incoming signal and the oscillator signal are then mixed to produce the correct IF difference signal. The mixer stage mixes the signal from the RF amplifier stage and the signal from the mixer stage and combines them. Since these two frequencies are separated by 45.75MHz, the IF signal, at this 45.75MHz frequency, appears in the output circuit where it is coupled to the IF amplifier.

REVIEW QUESTIONS

1. What are the frequency allocations for TV channels?
2. Name the various types of television VHF tuner.
3. What purpose does a balun serve in the antenna circuit?
4. What is the purpose of an RF amplifier stage in the television receiver?
5. What is the purpose of the oscillator?
6. What is the purpose of the fine tuning control?
7. What is the purpose of the fine tuning control?

The Video Channel

The video channel consists of the stages from the tuner to the picture tube—the video-IF amplifier, video detector and the video amplifier. These are the circuits which amplify and process the video signal for application to the picture tube to reproduce the picture.

VIDEO-IF AMPLIFIERS

The television receiver is a high-frequency superheterodyne, most of the gain is contributed by the IF amplifiers. IF stage gain is measured as shown in Fig. 1. Recall that there are actually two IF signals at the mixer output—the video IF and the sound IF. These two frequencies are separated by the 4.5MHz difference set by the transmitter. The response of the IF amplifiers is made wide enough that both frequencies are passed. In the video detector, the sound-IF and video-IF are beat together to produce the 4.5MHz intercarrier sound signal.

In early television receivers the sound and video IF signals were separated directly at the mixer output, and separate IF amplifiers were employed for the video and the sound. This method was called *split sound*; however it is not employed in any modern receivers. All modern receivers use the intercarrier principle.

I-F Requirements—The requirements of the television IF amplifier system are far more complex than the IF ampli-

(A) Test setup.

(B) Typical scope pattern.
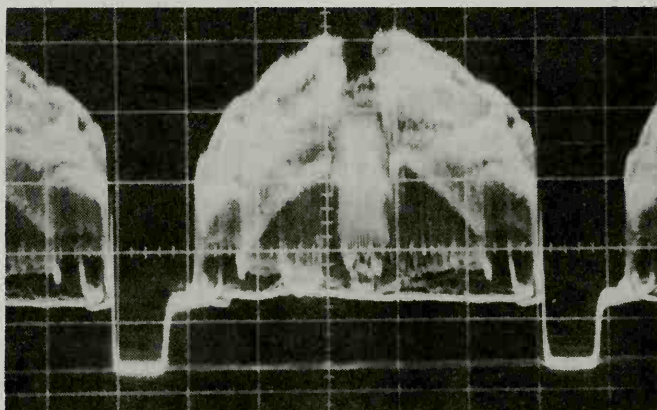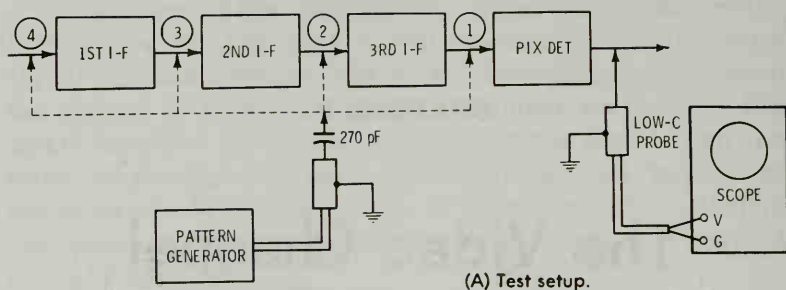
Fig. 1. Measurement of IF stage gain.

fiers in broadcast receivers. In broadcast receivers, the IF amplifiers must pass a band of frequencies only 10kHz wide. In FM receivers, the bandwidth requirements are only 200kHz. In a television receiver, however, the IF am- plier must pass a band of frequencies *5 megahertz* wide. In addition to the requirement of passing the wide band of frequencies, other frequencies must be attenuated so that they cannot cause interference in the desired channel. These frequencies are:

1. Sound carrier of the adjacent lower channel.

2. Video carrier with its modulation in the next higher adjacent channel.

In addition, the sound IF of the desired channel must be reduced to a level 23 to 26 db below the video carrier within the IF amplifier system. If the sound carrier is not reduced, sound bars (interference) will appear in the picture. Fig. 2 shows the basic IF and VHF frequency relations.

I-F RESPONSE curve markers: 39.75, 41.25, 41.67, 42.17, 42.67, 45.00, 45.75, 47.25

MARKER TITLE	ADJ PIX	SOUND	CHROMA	CHROMA (CARRIER)	CHROMA		REFERENCE	PIX	ADJ SND
I-F FREQUENCY	39.75 MHz	41.25 MHz	41.67 MHz	42.17 MHz	42.67 MHz		45.00 MHz	45.75 MHz	47.25 MHz
CH 4	73.25 MHz	71.75 MHz	71.33 MHz	70.83 MHz	70.33 MHz		68.00 MHz	67.25 MHz	65.75 MHz
CH 10	199.25 MHz	197.75 MHz	197.33 MHz	196.83 MHz	196.33 MHz		194.00 MHz	193.25 MHz	191.75 MHz
VIDEO/CHROMA	6.00 MHz	4.50 MHz	4.08 MHz	3.58 MHz	3.08 MHz		0.75 MHz	ZERO	1.50 MHz

Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 2. IF and VHF frequency relations.

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The number of stages of amplification varies among the different manufacturers and the intended application of the receiver (fringe or local reception). Sets with only one IF amplifier or as many as five stages have been produced. Most receivers, however, employ two or three stages of IF amplification.

In the previous chapter, it was stated that the use of 45.75 MHz as the video IF and 41.25MHz for the sound IF was practically universal in modern receivers. Formerly, many other frequencies were used as the sound IF. Some of them are as follows.

Video IF Carrier (megahertz)	Sound IF Carrier (megahertz)
15.2	10.7
22.9	27.4
25.75	21.25
26.1	21.6
26.2	21.7
26.4	21.9
26.25	21.75
26.6	22.1
26.75	22.25
37.3	32.8

Video-IF Response—Recall that in vestigial-sideband transmissions (Fig. 3A), the amplitude of the transmitted signal is practically constant from approximately 0.75MHz below the video carrier to 4.0MHz above the carrier. Also between 0.75- and 1.25 MHz below the carrier, a portion of the lower sideband is transmitted. Thus, if such a carrier and its sidebands were to be applied to a linear detector, the output would be as pictured in Fig. 3B. Obviously, such an output would not give the desired results. With the response of Fig. 3B, all objects which result in a video frequency up to 0.75MHz from the carrier would receive twice the amplification as those from 1.25 to 4.0MHz. Between 0.75- and 1.25 MHz, the response tapers gradually from 100% to 50%.

Some method of compensating for the increased low frequencies due to the double sideband transmission must be provided in the video IF amplifier. This compensation is provided by reducing the amplification at the carrier frequency and increasing it at the higher frequencies. Thus, the ideal video response should appear as shown by curve B in Fig. 4. Curve A in Fig. 4 shows the transmitted carrier. In curve B, the video carrier is set at the 50% point, and the areas between 0.75MHz above and below the carrier are less than 100% of the response. However, by adding the
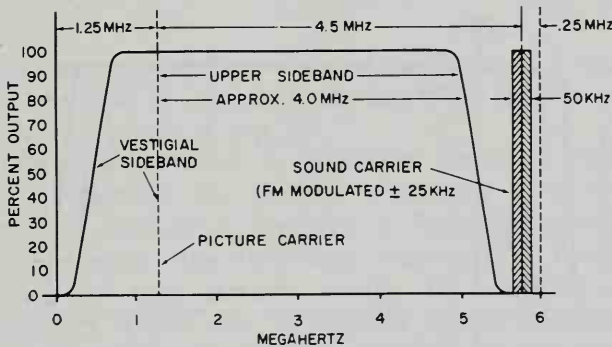
(A) Vestigial-sideband transmission.
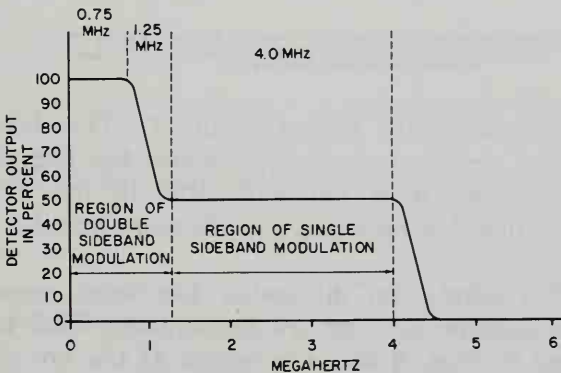
(B) Response obtained by linear detection of (A).

Fig. 3. The effect of linear detection of the carrier.

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portion of the response between 0.75MHz below the carrier and the carrier to the response between the carrier and 0.75MHz above the carrier, the curve at D will result. Thus, these two portions of the curve when added together result in an overall 100% response between the carrier and the 0.75-MHz point.

It is impossible to obtain the straight-line response of curve B in Fig. 4. Notice, however, the curve at C will also add to the desired response. At the high-frequency end of the response, the ideal curve is depicted by curves A and B. Usually, however, the high-frequency response is
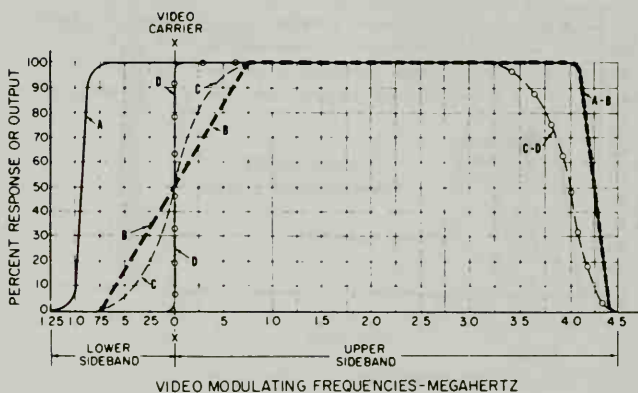
Fig. 4. Overall receiver characteristic required to compensate for vestigial-sideband modulation.

tapered off as shown by curves C and D. This tapering off at the high frequency end does reduce the fine details in the picture but it is not noticeable in the average scene. In practice, few receivers provide more than 3.0 MHz response.

Up to this point, the discussion has been concerned with the frequencies as they are transmitted. That is, the video carrier in Figs. 3 and 4 is shown at the low end of the response curve and the sound carrier is shown at the high end. Recall, however, that the receiver local oscillator frequency is higher than the transmitted carrier frequency;

therefore, in the IF amplifiers, the sound-IF will be located at the low end of the response curve and the video-IF will be at the high-frequency end. Also, in an actual receiver,

41.25 MHz SOUND CARRIER

45.75 MHz PICTURE CARRIER

Fig. 5. A typical video IF response.

39.75 MHz ADJACENT CHANNEL PICTURE

47.25 MHz ADJACENT CHANNEL SOUND
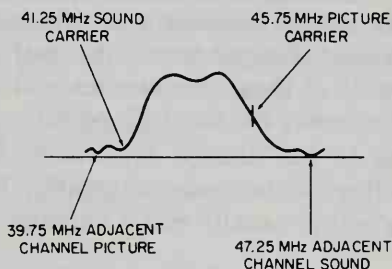
the ideal response of Fig. 4 is seldom obtained. The actual response of the IF amplifier section will usually appear similar to the curve of Fig. 5.

IF Traps—In addition to providing amplification of the desired frequencies, the video-IF amplifiers must also prevent certain undesired frequencies from being amplified and passed on to the following stages. This function is performed by trap circuits in the IF amplifier stages. Based on the 41.25- and 45.75-MHz sound- and video-IF frequencies, traps are usually included for the following frequencies.

1. 39.75-MHz adjacent-channel sound carrier.

2. 41.25-MHz co-channel (desired) sound carrier.

3. 45.75-MHz adjacent-channel video carrier.

IF TRANSFORMER

TO NEXT STAGE

Fig. 6. The shunt trap.

TRAP

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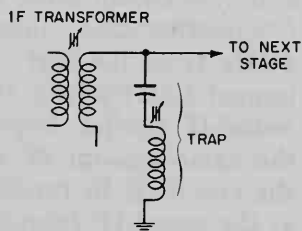
Two types of traps are employed—shunt and absorption traps.

The shunt trap (Fig. 6) consists of a series resonant tank connected in shunt (parallel) with the input circuit. This circuit presents a low impedance to any signals at the resonant frequency of the coil and capacitor. Thus, any signals at these frequencies will be shunted to ground. The adjustment on the coil permits precise adjustment of the trap to the desired frequency. Either the coil or the capacitor can be made adjustable; however, in actual practice, the coil is usually made adjustable as shown in Fig. 6.
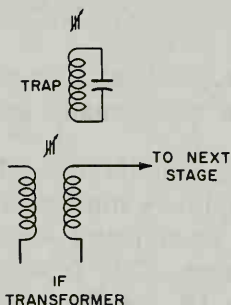
Fig. 7. The absorption trap.

The absorption trap (Fig. 7) consists of a parallel-resonant circuit inductively coupled to the IF transformer. At the resonant frequency, maximum current flows in the trap circuit. This current must be absorbed from the IF transformer; therefore, any currents at the trap resonant frequency present in the IF transformer secondary will be removed.

IF Amplifier Circuits—As mentioned previously the IF amplifier circuit must be capable of passing a wide band of frequencies. The video modulation extends approximately 4MHz from the carrier. In addition, the sound-IF carrier located 4.5MHz from the video carrier must be passed. The sound-IF carrier, however, must not be allowed to receive the same amount of amplification as the video carrier if the circuit is to function properly. Usually, the amplitude at the sound-IF frequency should be approximately 10% of the peak level. For this reason, traps tuned to the sound-

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IF frequency are usually included in the video IF circuit to reduce the sound-IF frequencies.

An ordinary amplifier stage would be unable to amplify the wide band of frequencies necessary in the IF system. Therefore, some means must be employed to increase the bandwidth. Three basic circuits are used for video-IF amplifiers. They are:

1. Overcoupled amplifiers. (See Fig. 8).

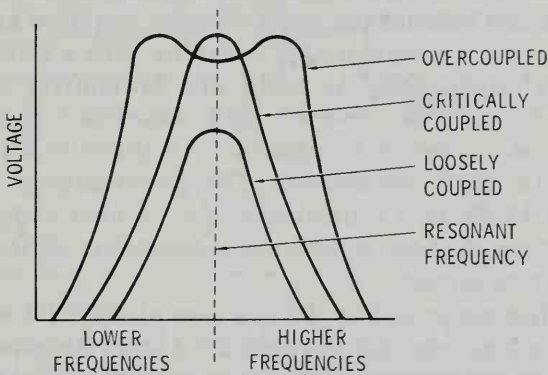2. Stagger-tuned amplifiers. (See Fig. 9).

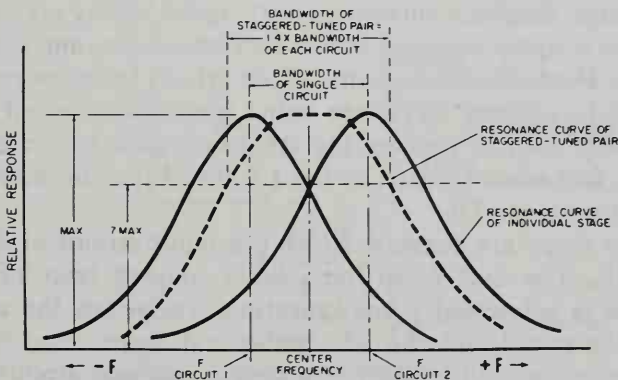Fig. 8. Examples of loose coupling, critical coupling, overcoupling.

Fig. 9. The effect of staggered tuning.

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Stagger-Tuned IF—In the stagger-tuned IF system, each IF stage is tuned to a different frequency in the passband. Fig. 9 shows the effect of stagger tuning. Two stages are tuned to two separate frequencies. The response curves of the two individual stages are indicated by the solid lines in Fig. 9. However, the overall response of the two stages will be as indicated by the dotted line. Thus, by proper choice of frequencies and circuits, the response can be widened to obtain the desired response.

Fig. 10 depicts a basic transistor IF amplifier configuration. The third IF transistor operates as higher power than the first two because the video detector requires appreciable power input. Transistor Q25 operates with a collector voltage of approximately 15 volts, and an emitter current of about 15 ma. The collector load impedance is nominally 1000 ohms; however, transformer T8 provides some stepup voltage for the video detector. The power gain of this stage is about 18 db. It is neutralized by a 1.5-mmf capacitor connected from the base of Q25 to the secondary of the collector output transformer.

The first stage in Fig. 10 operates at 15 volts on the collector and an emitter current of 4 ma. Reverse AGC is applied to the base of Q27; this is conventional AGC action in which the transistor is AGC-biased toward cutoff. The minimum collector current of Q27 under strong-signal conditions is approximately 50 μa. Q27 has a dynamic range of 40 db. Diode D12 is a clamp diode which becomes reverse-biased to prevent Q27 from being completely cut off when the AGC voltage reduces the RF tuner gain to a very low value. Q27 is neutralized by the 1.5-mmf capacitor connected from its base to T6.

Two traps are connected into the input circuit of Q27 in Fig. 10 . The first is an inductively coupled trap, and the second is a bridged-T configuration. These are the accompanying-sound and the adjacent-sound traps, respectively. The collector load for Q27 is a simple resonant circuit, with a tap to provide an out-of-phase neutralizing signal. Transistor Q26 is base-driven via capacitance coupling. This sec-
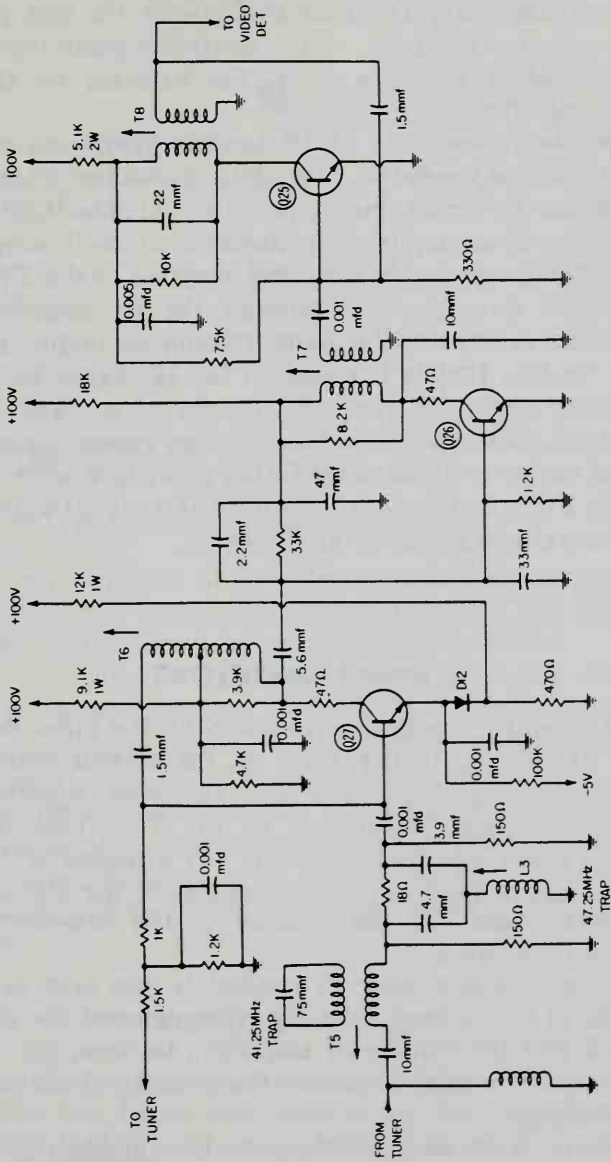
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Fig. 10. Video IF amplifier circuit.

ond stage is not AGC-controlled, and operates continuously at maximum gain. The base bias circuit for Q26 provides some negative feedback, which assists in obtaining a properly-shaped IF response curve. The collector for Q26 is a bifilar transformer.

Preliminary analysis of IF trouble symptoms requires tests to isolate the defect to a particular stage. This can be done either by signal tracing or by signal substitution. Signal tracing is accomplished by means of an oscilloscope with a demodulator probe. In turn, the progress of the TV signal is checked stage-by-stage through the IF amplifier. The chief disadvantage of the signal-tracing technique is in the heavy loading that is imposed on the IF stages by the demodulator probe. In turn, the results of a signal-tracing test are not always conclusive. For this reason, many technicians prefer a signal-substitution procedure, such as outlined in Fig. 11. A generator is used as a signal source, and the picture tube serves as an indicator.

VIDEO DETECTORS

The video-IF amplifier is followed by the video detector, which is essentially the same as the second detector in AM broadcast or short-wave radio receivers. However, two significant circuit differences in the TV video detector must be taken into consideration: (1) a means of compensation must be used to prevent the loss of the higher video frequencies, and (2) the polarity of the detector output must be considered.

The video signal may be applied to the grid or to the cathode of the picture tube. To what element the signal is applied, and the number of amplifiers between the detector and the picture tube determine the polarity of the detector-output signal.

If there is an even number of video amplifying stages between the detector and the picture-tube grid, the detector output must be negative-going. In other words, an increase
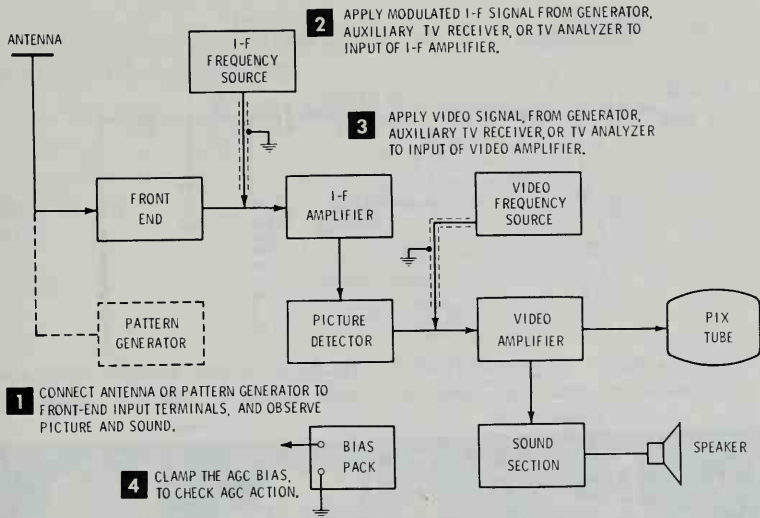
Fig. 11. Pointers for isolating defect to IF strip.

in IF carrier strength at the detector results in a more nega-
tive video signal with respect to ground. Fig. 12A shows a
detector which supplies a negative picture polarity.

If an odd number of video amplifying stages are em-
ployed (in most instances, this will be a single stage) and
the video signal is applied to the grid of the picture tube,
the detector must be connected as shown in Fig. 12B.
This circuit with the plate of the diode connected to the
high side of the video coupling circuit, produces a video
output which becomes more positive as the video carrier
strength is increased. Fig. 13 shows diode polarity identi-
fications.

VIDEO AMPLIFIERS

The output of the video detector seldom exceeds a few
volts. Since the picture tube requires a grid swing of approx-
imately 40 volts for its range of black to white, the signal
from the video detector must be amplified through one or
more stages of video amplification.

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(A) Video output increases negatively with respect to ground as carrier increases.

(B) Video output increases positively with respect to ground as carrier increases.
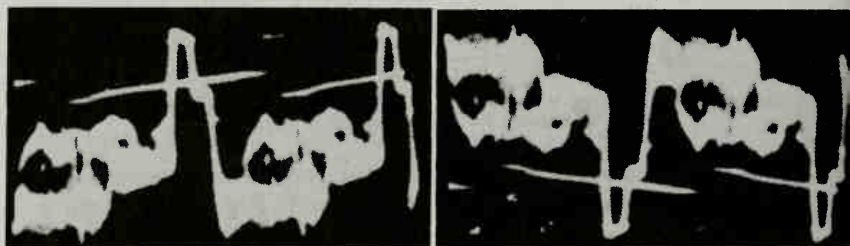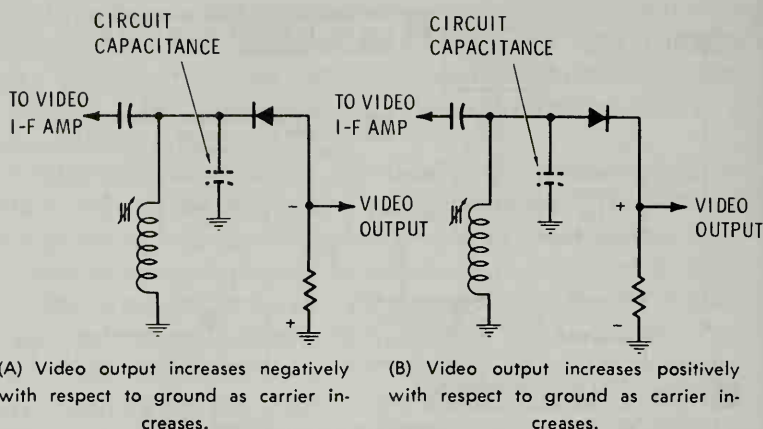
(C) Appearance of positive-going and negative-going video signals on the oscilloscope screen.

Fig. 12. Diode video-detector output polarity.

In our study of the nature of the video modulating signal, we have seen that the range of frequencies extends from 30 Hertz to over four million Hertz per second. For an amplifier to provide uniform gain over this extended band, compensating circuits must be used. The basic circuit, to which correction networks are applied, is the familiar resistance- and capacitance-coupled audio amplifier.

Three separate methods of extending the range of a resistance- and capacitance-coupled amplifier for video use are:

1. Low values of collector load or coupling resistance.

2. Low-frequency compensation to overcome effects of coupling network, unless direct coupling is used.

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3. High-frequency compensation to overcome effects of total circuit capacitance.
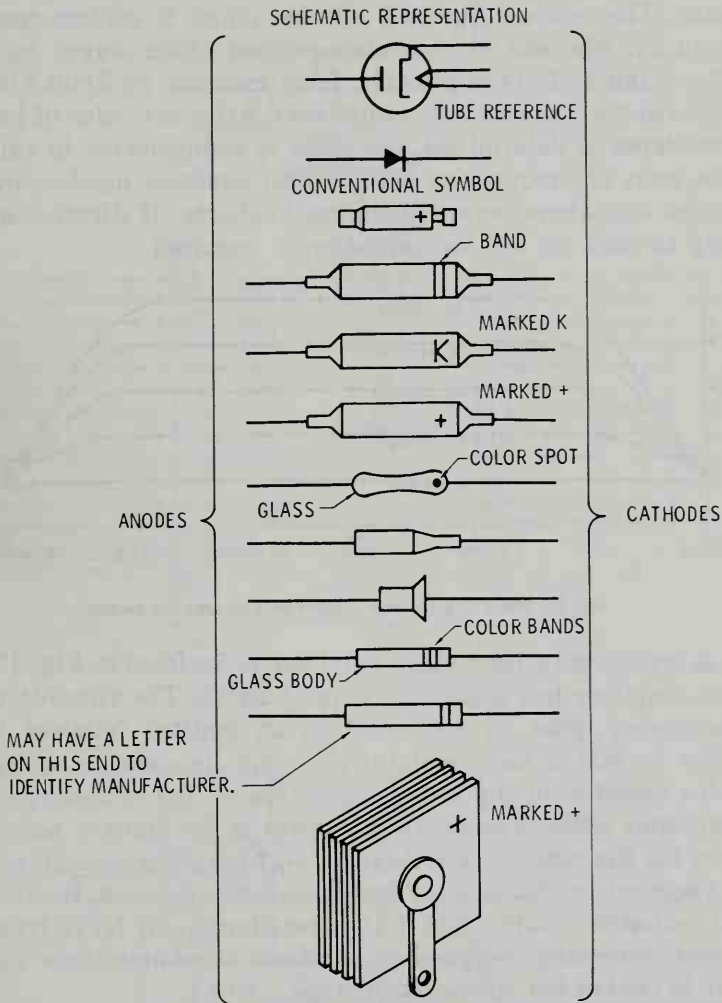
Courtesy Heath Co.

Fig. 13. Diode polarity identifications.

Low Value of Collector Load—Fig. 14 shows the effect of changing the value of the collector-load resistor. The band

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of video frequencies over which the output is flat is greatly
extended as the coupling resistance is decreased. The choice
of load resistor is a compromise between bandwidth and
gain. The voltage gain of a video stage is seldom more
than 20, whereas in resistance-coupled audio stages gains
of as high as 150 are possible. Load resistors of 2,000-4,000
ohms are common in video amplifiers. After the value of load
resistance is determined, the stage is compensated to raise
the gain at frequencies below approximately one-hundred
cycles and above several hundred kilohertz. If direct coup-
ling is used, no LF compensation is required.
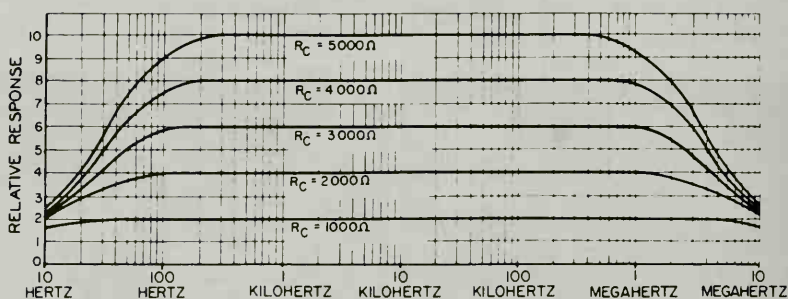
Fig. 14. Effect of plate load resistor on gain and bandwidth.

A typical transistor video amplifier is depicted in Fig. 15;
this amplifier has a nominal gain of 28 db. The video-drive
transistor, Q204, is connected as an emitter follower in
order to match the comparatively high impedance of the
video detector to the input impedance of the video-output
transistor Q205. The contrast control is the emitter resist-
ance for the video-driver stage. A 4-μf coupling capacitance
is required to obtain good low-frequency response, because
this capacitor works into a 10-k resistance. An NPN tran-
sistor, especially designed to handle a large-amplitude sig-
nal, is used in the video-output stage.

The output signal voltage provided by the video amplifier
in Fig. 15 ranges from 25 to 50 volts p-p. Note that the
collector of the video-output transistor is returned to a 140-
volt power supply. With the contrast control turned to

Fig. 15. A transistor video-amplifier circuit.

maximum, an output signal amplitude of 100 volts p-p can be provided. A light-dependent resistor (LDR201) is used to automatically vary the picture contrast and brightness as the ambient room lighting varies. This device acts to increase or decrease the gain of the video amplifier, thereby automatically controlling the contrast. Since the collector of Q205 is DC-coupled to the cathode of the picture tube, the brightness is also controlled automatically.

Preliminary analysis of trouble symptoms in the video-amplifier section is generally made with an oscilloscope, as depicted in Fig. 16. Wave-forms are checked for amplitude (peak-to-peak voltage value), and for distortion. Instead of making a frequency response check, a square-wave test may be used. If a video amplifier is in normal operating condition, it will pass a 100 kHz square wave without substantial distortion. Measurement of DC voltage and resistance values are basic in pinpointing defective components. These tests apply to solid-state video amplifiers, as well as to tube-type amplifiers. Note that receiver service data often provides resistance charts to facilitate in-circuit resistance measurements. A typical chart is shown in Fig. 17. In the case of a solid-state receiver, in-circuit resistance measurements should be made with an ohmmeter that applies less than 0.08 volt across points under test, as noted in the chart. A hi/lo pwr ohmmeter is provided in the electrical multimeter illustrated in Fig. 18. The advantage of a lo-pwr ohmmeter in solid-state troubleshooting is that normal semi-conductor junctions will not be "turned on" during in-circuit resistance measurements. A "turned on" junction represents an unexpected shunt-resistance path that makes the resistance measure virtually meaningless.

BRIGHTNESS CONTROL

At several points in the text, we indicated that the variation of video or picture signal on the control grid of the picture tube is responsible for the instantaneous changes of
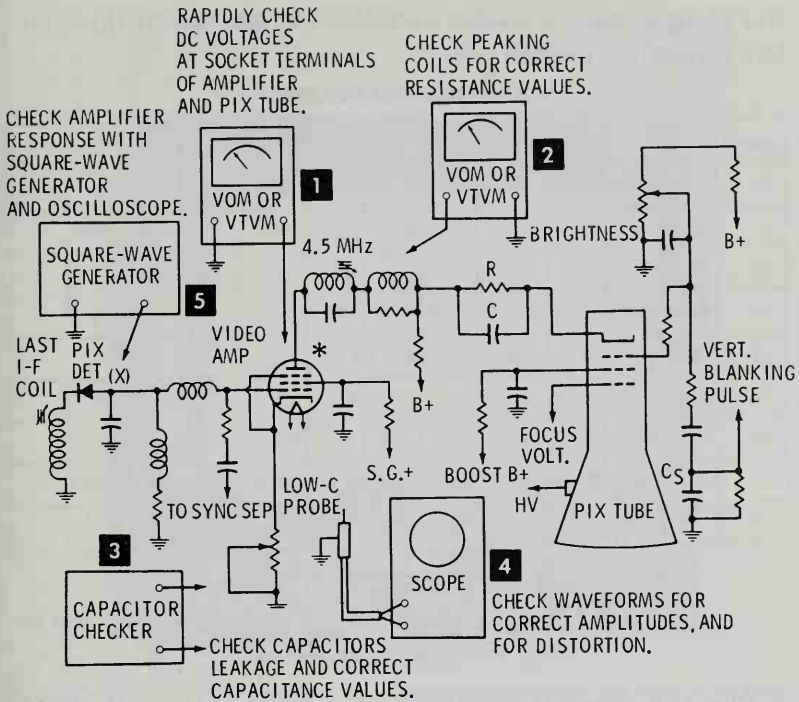
Fig. 16. Troubleshooting procedure for preliminary analysis of video amplifier malfunctions.

spot illumination which makes up the elements of the picture. When the signal voltage on this control element changes in a negative direction, a darker spot is produced on the screen. Finally, at some critical negative voltage, the spot of light is entirely extinguished.

One of the essential controls of the television receiver is a bias adjustment on the grid. This adjustment assures that the blanking level, or pedestal, of the signal occurs at the black point. Fig. 19 shows two bias systems in which the voltage established by adjustment of the brightness control biases the control grid with respect to the cathode and determines the correct picture brightness. Because of the polarity of the video signal in Fig. 19A, the signal from

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the plate of the video-output tube is connected to the control grid of the picture tube.

RESISTANCE MEASUREMENTS

Component	E	B	C	Component	E	B	C	Component	E	B	C	
Q4	180 Ω	1400 Ω	400 Ω	Q14	80 Ω	15 K	3500 Ω	Q23	70 Ω	70 Ω	0 Ω	
Q5	220 Ω	1400 Ω	380 Ω	Q15	120 Ω	3500 Ω	2000 Ω	Q24	140 Ω	800 Ω	1700Ω	
Q6	180 Ω	1200 Ω	110 Ω	Q16	1000 Ω	55 K	180 Ω	Q25	70 Ω	2000 Ω	0 Ω	
Q7	2400 Ω	3000 Ω	300 Ω	Q17	380 Ω	50 K	470 Ω					
Q8	470 Ω	2400 Ω	45 K	Q18	1500 Ω	1200 Ω	82 Ω					
Q9	2700 Ω	3000 Ω	500 Ω	Q19	33 Ω	8000 Ω	500 Ω	Q26–VHF	180 Ω	2800 Ω	180 Ω	
Q10	150 Ω	3000 Ω	1200 Ω	Q20	80 Ω	180 Ω	135 Ω	Q27–VHF	330 Ω	1800 Ω	600 Ω	
Q11	1200 Ω	1200 Ω	80 Ω	Q21	45 Ω	15 K	800 Ω	Q28–VHF	80 Ω	550 Ω	3200 Ω	
Q12	1200 Ω	1200 Ω	0 Ω	Q22	80 Ω	1200 Ω	8 Ω	Q29–UHF	390 Ω	1200 Ω	60 Ω	

TAKEN WITH OHMMETER APPLYING A
MAXIMUM OF 0.08 VOLT ACROSS POINTS UNDER TEST

Courtesy Howard W. Sams Co.

Fig. 17. Resistance measurements.

Fig. 19B shows the video signal applied to the cathode of the picture tube. In either case, the brightness control is a voltage adjustment of the bias between the control grid and cathode, and establishes the correct blanking or black level.

INTEGRATED CIRCUITS

Integrated circuits are being used to a greater extent than previously in RF and IF amplifiers. Most IC units are based on the differential-amplifier configuration shown in Fig. 20. The transistors are formed in a single chip. Q1 and Q2 are called a *differential pair;* Q3 is termed a *constant-current sink.* Adjustment of the base voltage V_{B3} determines the current I_{C3}, and, in turn, the operating voltage of the amplifier circuit. The total collector current I_{C3} branches through Q1 and Q2 in accordance with the applied voltages V_{B1} and V_{B2}.
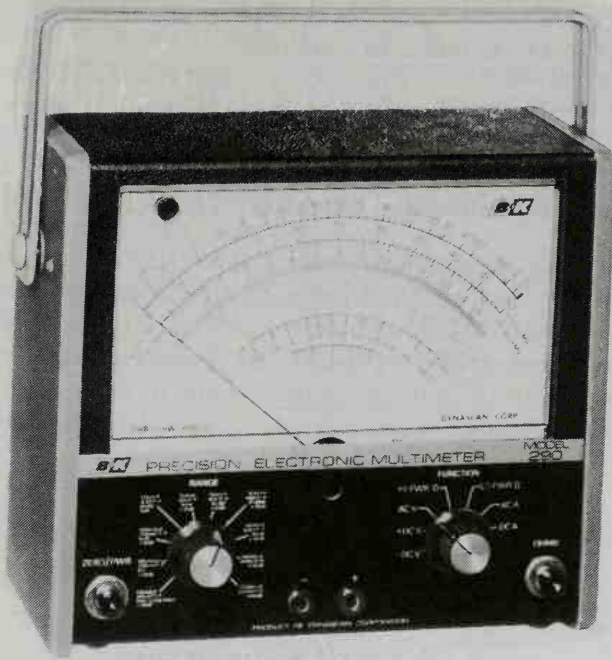
Fig. 18. An electronic multimeter that provides hi-pwr and lo-pwr ohmmeter functions.

(A) Video signal applied to grid.

(B) Video signal applied to cathode.
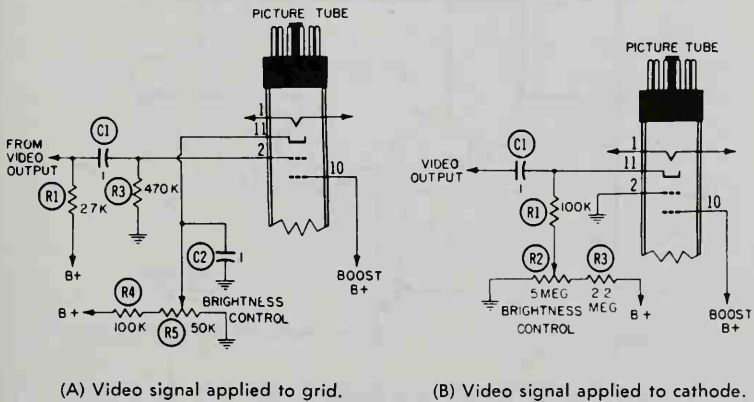
Fig. 19. Brightness-control circuits.

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Use of a differential pair makes the amplifier relatively free from effects of temperature changes.

With reference to Fig. 21, Q1 operates in a common-emitter configuration with the IF signal applied to the base. In turn, Q1 drives Q2 and Q3, which operates in a common-base configuration called a *cascode pair*. It employs a pair of transistors connected in series. The collector of Q3 is

Fig. 20. Basic integrated circuit configuration.

Fig. 21. Configuration of an integrated IF amplifier stage.

effectively grounded, and the IF signal output is taken from the collector of Q2. Diode D1 provides delayed AGC; the AGC 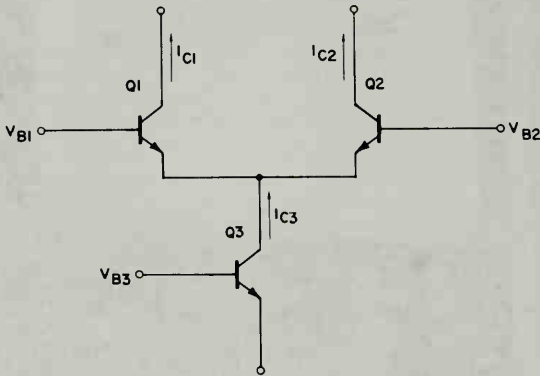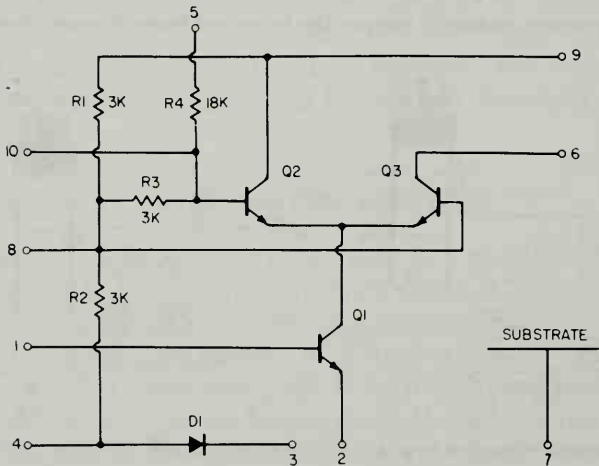voltage varies over a range of approximately 0.86 volt in normal operation. If the AGC voltage exceeds the nominal base voltage on Q2 by 57 mv in this example, Q2 will be cut off and the collector current will be confined to Q1 and Q3. Since Q2 is cut off, the stage gain is minimum under this condition of AGC voltage.

Next, if the AGC is less than the nominal base voltage by at least 57 mv in Fig. 21, all of the collector current from Q1 will pass into the emitter of Q2. Q3 is biased to cutoff. In turn, Q2 develops an amount of gain that depends on the particular value of applied AGC voltage. A supply voltage of 20 volts is used in this example, and is applied to terminal
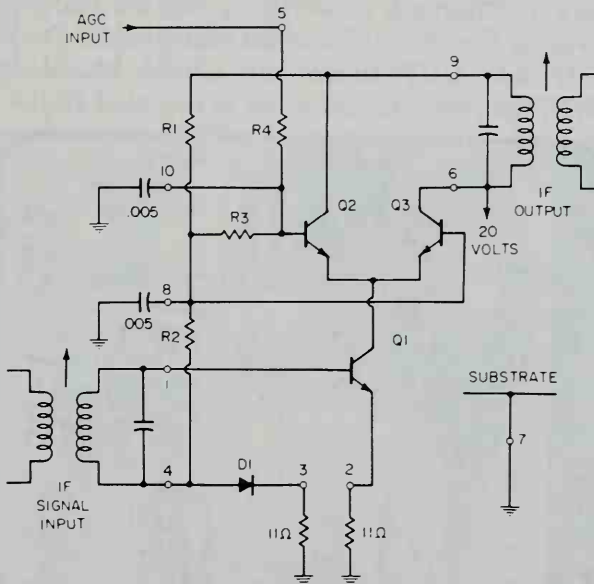

Fig. 22. An integrated IF circuit showing connections to external components.

6 as shown in Fig. 22. Terminals 8 and 10 are bypassed to ground with 0.005-μf capacitors; terminals 2 and 3 are connected to ground via 11-ohm resistors. The substrate,

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terminal 7, is grounded. Ordinary slug-tuned coils and ca-
pacitors are used to couple one IC to the next.

MODULAR CONSTRUCTION

Various receiver designs include modular construction.
A module, such as illustrated in Fig. 23, is similar to a
printed circuit board, except that it is designed to plug into
the receiver. It can be unplugged in turn, without any dis-
connection of leads. Modular construction facilitates
troubleshooting procedures because a known good module
can be quickly substituted for a suspected module. In turn,
if normal operation is restored, the defective module can be
repaired at any convenient time. Some receivers are ex-
tensively modularized, as shown in Fig. 24. However, there
are always a few chassis-mounted components. For example,
the VHF and UHF tuners are always chassis-mounted.
Similarly, the power transformer is mounted on the chassis.
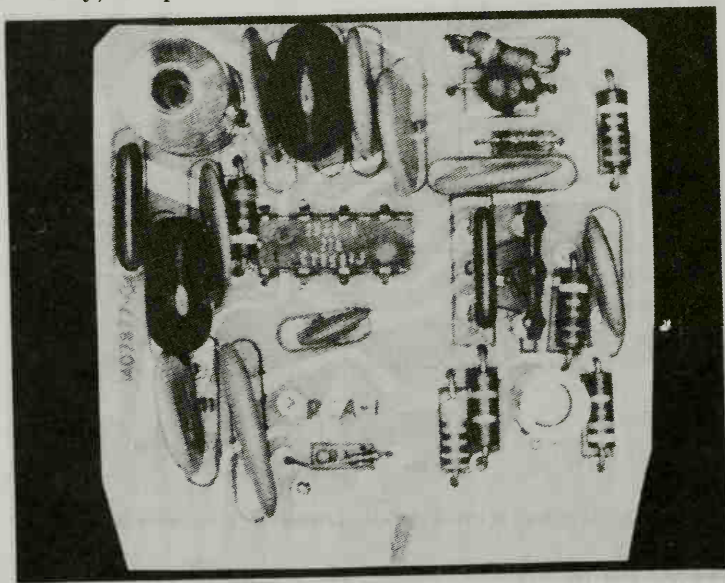
Courtesy RCA Corp.

Fig. 23. A module for a television receiver.
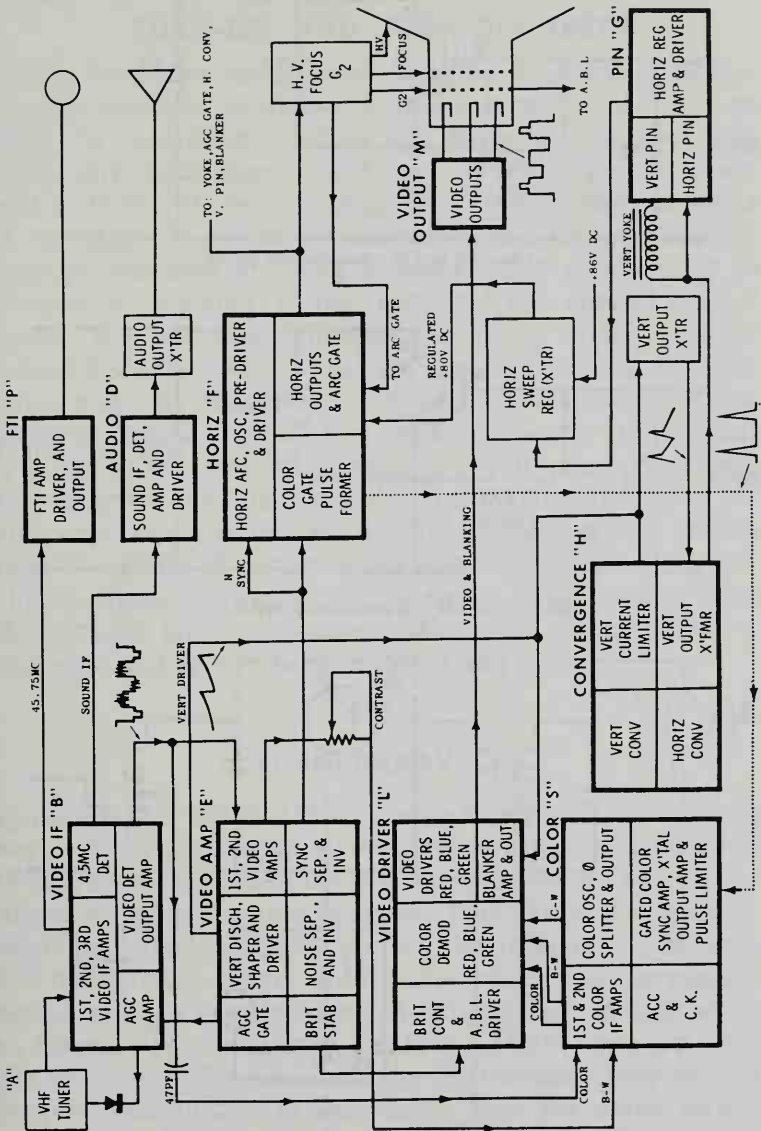
Courtesy Motorolo Consumer Products, Inc.

Fig. 24. Layout of a typical modularized television receiver.

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(A) Turn-off test in a two-battery circuit.

(B) Turn-off test in a one-battery circuit.

(C) Turn-on test in a one-battery circuit.

Fig. 25. Basic in-circuit turn-off and turn-on transistor tests.

TURN-ON AND TURN-OFF TESTS

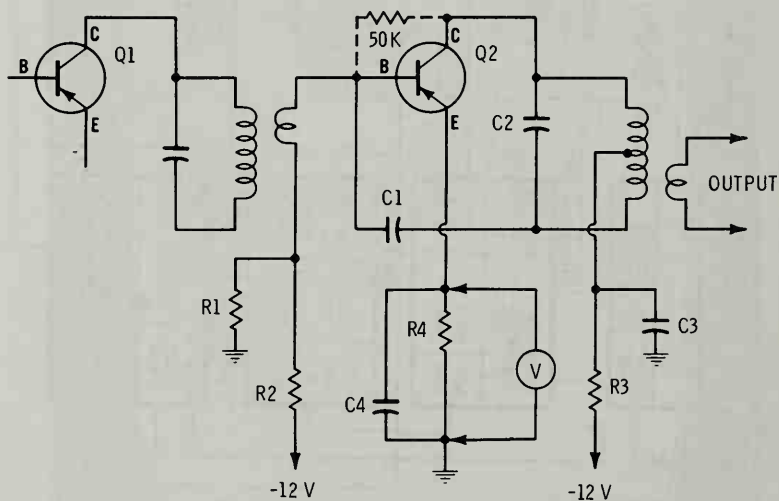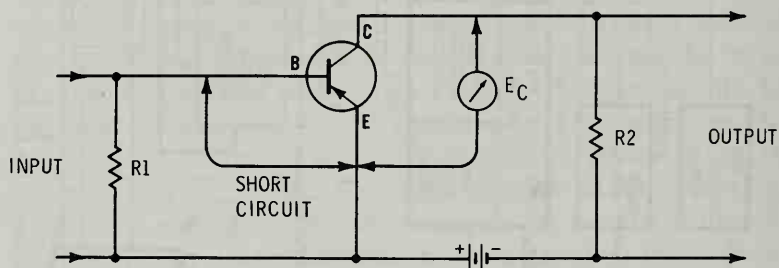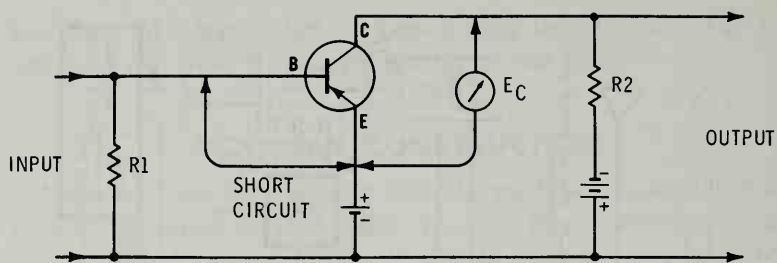If a transistor is suspected of being defective, it is frequently possible to make in-circuit turn-off and turn-on tests, to determine whether the transistor is workable. These are quick-checks that provide basic go/no-go answers. With reference to Fig. 25, a turn-off test is made in this type of circuit by measuring the collector-emitter voltage, and then applying a base-emitter short-circuit to observe any change. If the transistor has normal control action, the voltmeter indication jumps up to the collector supply-voltage value when the short-circuit is applied. Otherwise, the transistor is defective and should be unsoldered from its circuit, and replaced. Next, a turn-on test is made by temporarily connecting a 10K resistor between the collector and base terminals of the transistor. A DC voltmeter is connected across the emitter resistor in the type of circuit. If the transistor has normal control action, the voltmeter indication will increase substantially when the forward bias is increased. Otherwise, the transistor is defective and should be unsoldered and replaced.

SUMMARY

In early television days the sound and video IF signals were separated directly at the mixer output, and separate IF amplifiers were used for the video and sound. This method was called split sound; however, it is not used in modern receivers today. All receivers use the intercarrier system. The intercarrier system is a receiver which uses the picture carrier and the associated sound-channel carrier to produce an intermediate frequency equal to the difference between the two carrier frequencies. This intermediate frequency is frequency-modulated in accordance with the sound signal.

The requirements of the television IF amplifier system are far more complex than the IF amplifiers in broadcast receivers. In broadcast receivers, the IF amplifier must pass

a band of frequencies only 10 kHz wide. FM receivers have a band width of 200 kHz. In television receivers, the IF amplifier must pass a band of frequencies 5 megahertz wide.

Vestigial sideband is an amplitude-modulated transmission in which a portion of one sideband has been largely suppressed by a transducer having a gradual cutoff in the neighborhood of the carrier frequency.

REVIEW QUESTIONS

1. What frequencies must the IF amplifier pass in AM receivers? FM receivers? TV receivers?
2. What are the video IF and sound IF frequencies used in modern TV receivers?
3. Explain vestigial-sideband transmission.
4. What is the purpose of using IF traps?
5. What is the advantage of a lo-pwr ohmmeter?
6. How does a module differ from a PC board?

Sync and AGC Circuits

In commercial receivers, we find circuits in which the sync pulses are separated from the composite video signal by clippers. Processing circuitry develops sync waveforms of suitable polarity, separates the vertical-sync pulses from the horizontal sync pulses, clips and levels the pulse trains, and provides either single-ended or double-ended output as required by subsequent receiver circuits. Sync takeoff may be made either in the video-detector or video-amplifier section. A sample of the composite video signal is fed to a clipper circuit, such as shown in Fig. 1. Either a diode or a transistor may be used as a clipping device. The advantage of a transistor is its amplification of the clipped pulses. In Fig. 1(A), the incoming composite video signal is coupled to the diode circuit via capacitor C. This coupling capacitor removes the DC component from the composite video signal, and also provides signal-developed bias across the diode.

Signal-developed bias provides the best separating action when the incoming signal amplitude varies, or when hum voltage is mixed with the composite video signal, as illustrated in Fig. 2(C). The clipping level in the waveform is automatically maintained because the value of the signal-developed bias is proportional to the amplitude of the applied signal. Note also that coupling capacitor C has comparatively great reactance at 60 Hz, and tends to suppress hum voltage. Signal-developed bias is produced in Fig. 1(A) as follows: Positive portions of the applied wave-
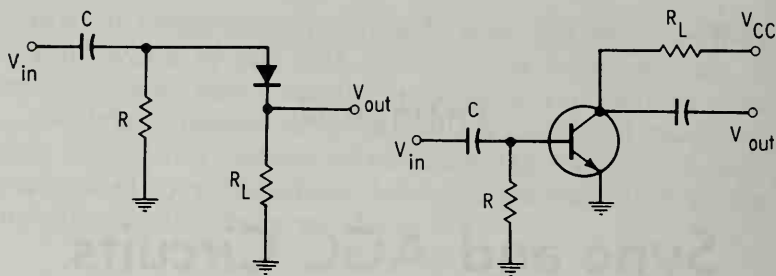
(A) Diode sync separator.

(B) Transistor sync separator.
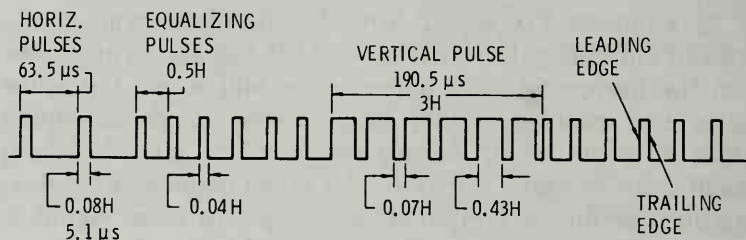
(C) Stripped sync output.

Fig. 1. Either a diode or a transistor may be used as a sync separator.

form cause diode conduction, and negative portions are blocked by the back resistance of the diode. Forward current flow through the diode develops a negative charge on the right-hand plate of capacitor C. In turn, the diode becomes reverse-biased as a voltage that depends on the amplitude of the positive excursion of the video signal. Between sync pulses, the charge on C decays at a rate that depends on the RC time-constant of the circuit. When R and C have correct values, clipping occurs at the black level in the composite video signal. Clipping action is checked to best advantage with an oscilloscope. An oscilloscope control familiarization diagram is shown in Fig. 3.

Transistors are also used to perform much the same functions. Fig. 4 shows a typical transistor limiter configuration. The collector-current waveform is limited be-
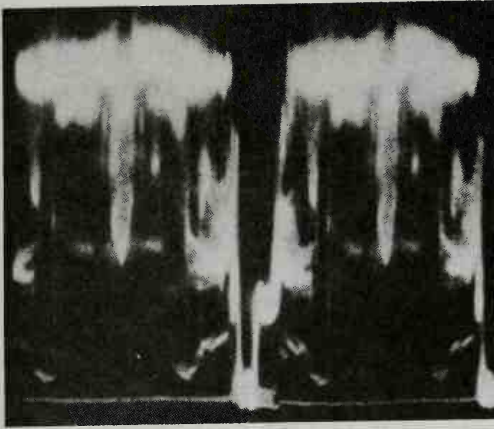
(A) 7875 Hz deflection.
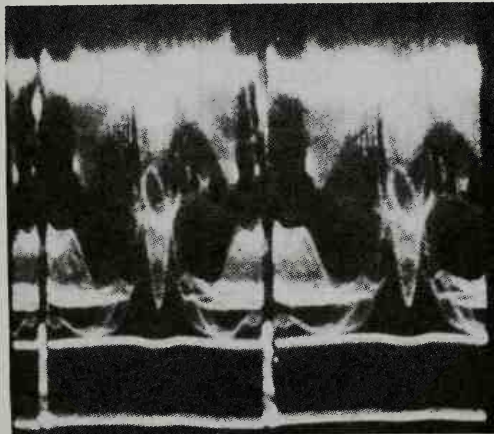
(B) 30 Hz deflection.
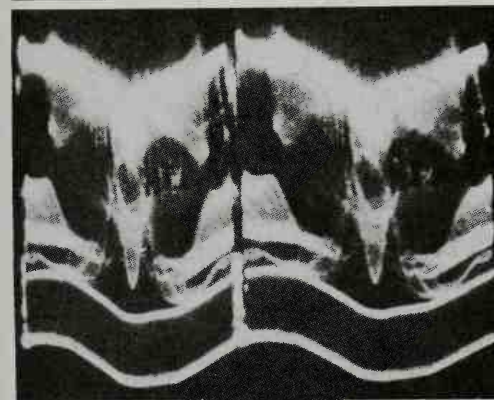
(C) Composite video signal with excessive 60 Hz hum.

Fig. 2. Normal proportions of sync-pulse and camera signal amplitudes.

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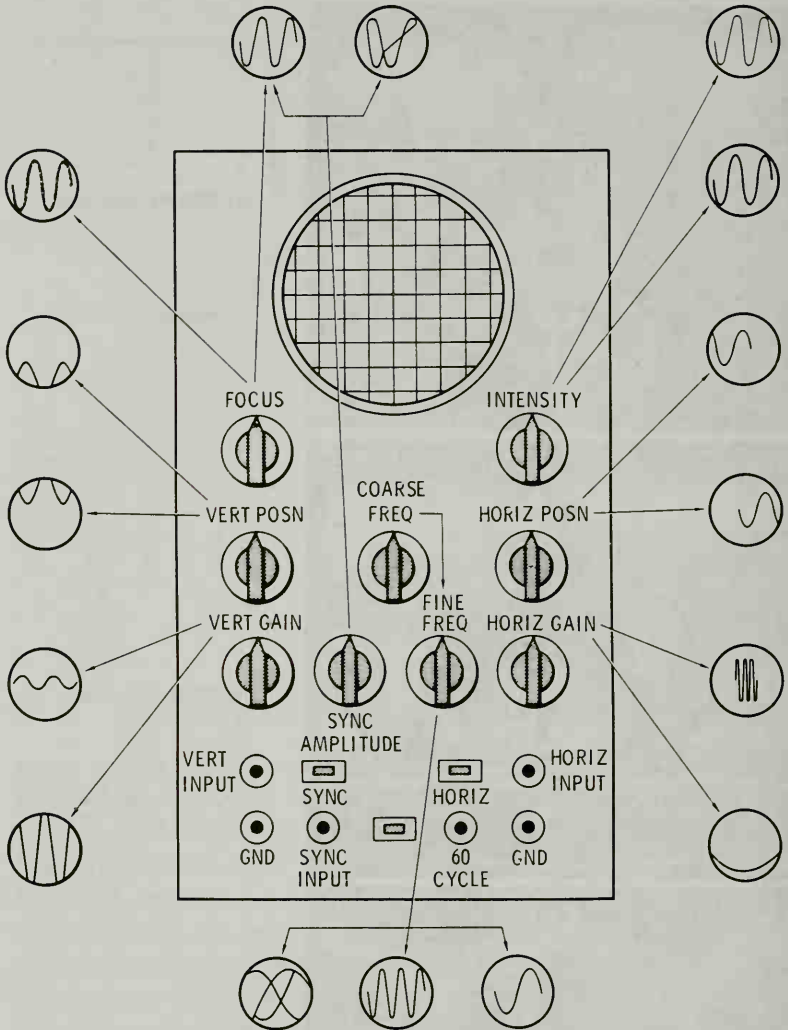
Fig. 3. Oscilloscope control familiarization.

cause the base drive voltage swings the base past the cutoff point. An example of saturation limiting is seen in Fig. 5. The collector-current waveform is limited because the base drive voltage swings the base past the saturation point. Note that when a transistor is saturated, the collector-current flow is so heavy that the voltage drop across
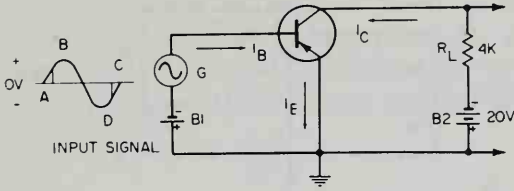
(A) Schematic.
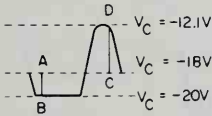
(B) Output signal.
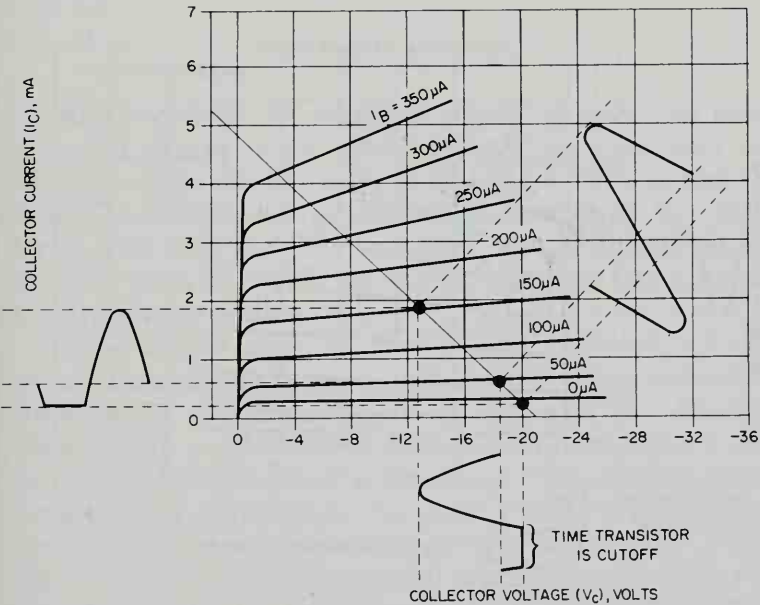
(C) Collector current curve.

Fig. 4. Cutoff using PNP transistor.

the collector load resistor brings the collector voltage down to a very low value.

Conversely, transistors are employed to obtain clipping action. Fig. 6 depicts a negative-peak clipper. The input

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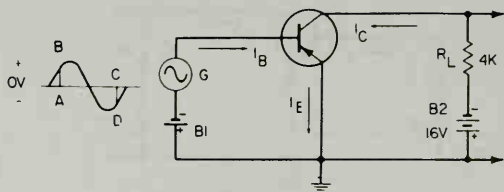
(A) Schematic.

(B) Output signal.
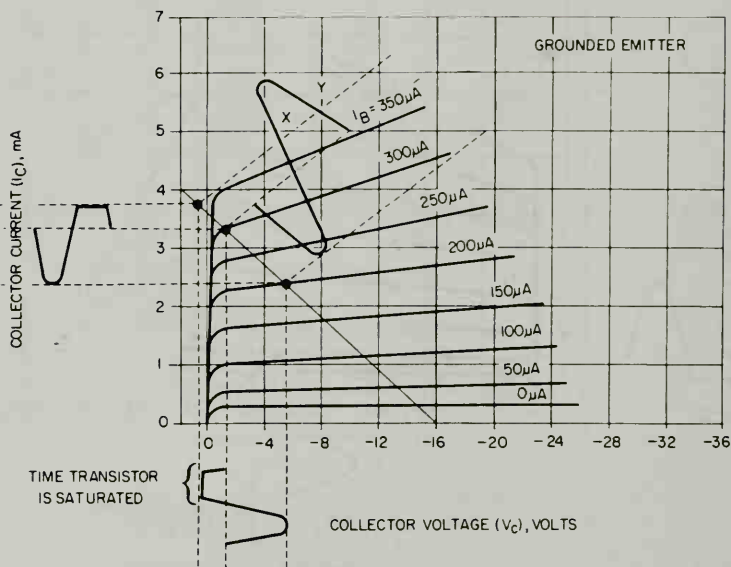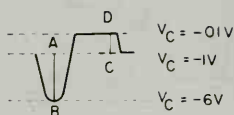
(C) Collector current curves.

Fig. 5. Saturation limiting using PNP transistor.

signal causes the base to draw current on negative half-cycles. In turn, the coupling capacitor is charged and applies a positive signal-developed bias voltage on the base.

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In turn, the transistor is reverse-biased in the presence of signal. Between successive signal peaks, some of the bias voltage leaks to ground. Therefore, the peaks of the applied waveform are clipped, and appear in the output circuit.
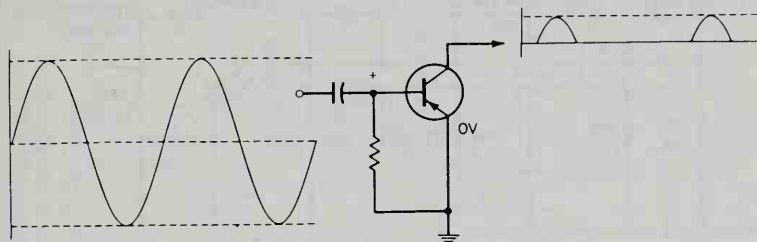
Fig. 6. Negative-peak clipper.

Many transistor TV receivers employ at least two sync-separator stages. Each stage operates as a clipper; the first stage clips off the top portion of the waveform, and the second transistor clips off the bottom portion of the waveform. Note that the first transistor inverts the waveform polarity, thus providing for bottom-clipping. Q14 operates chiefly as a saturation clipper.

In the second stage of Fig. 7, Q15 is biased 0.3 volt beyond cutoff by signal-developed bias in normal operation. Accordingly, the first 0.3 volt of the sync tips becomes clipped. Q15 is also driven into collector saturation, and thereby clips any residual video signal. The coupling capacitors tend to differentiate the sync waveform; therefore, C94 and R75 are included to provide integrating action that tends to restore the normal waveshape. Another circuit action provided by C94 and R75 is due to the impedance that they provide between the collector of Q14 and the base of Q15. This prevents overdriving of Q15 on strong signals, which would result in excessive increase of pulse width at the collector of Q15.

Preliminary analysis of trouble symptoms in the sync section is made as shown in Fig. 8.

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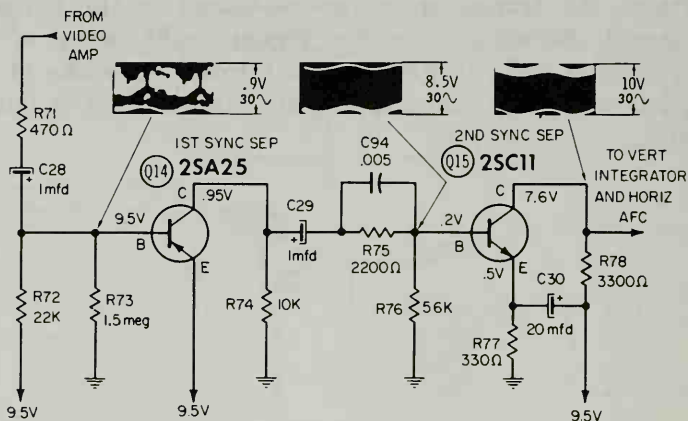
Fig. 7. A typical transistor sync-separator configuration.

SORTING OF THE INDIVIDUAL
HORIZONTAL AND VERTICAL PULSES

In the foregoing description of the various methods of separating the synchronizing pulses from the composite video signal, only the narrow horizontal pulses were mentioned. The longer vertical pulses are clipped from the signal in the same separation process.

After the sync pulses have been removed from the video signal, the vertical pulses must be sorted from the horizontal pulses; and each one must be fed to its respective deflection-scanning system. Since the horizontal and vertical pulses are equal in amplitude, the methods of separation for clipping them from the video signal cannot be used to distinguish between them. They do, however, differ in time duration. It is on this basis that sorting is accomplished.

We will now consider the action of such systems as differentiating networks for removing horizontal pulses and integrating networks for the vertical pulse acceptance.

Horizontal-Pulse Separation—The horizontal pulses of the transmitted signal are approximately five microseconds

in duration. These pulses are impressed on a circuit of the type shown in Fig. 9C, which is known as an R-C differentiating circuit.

Differentiation means the breaking down of a quantity into a number of small parts. The pulses in Fig. 9A are made into smaller parts, as shown in Fig. 9B by the
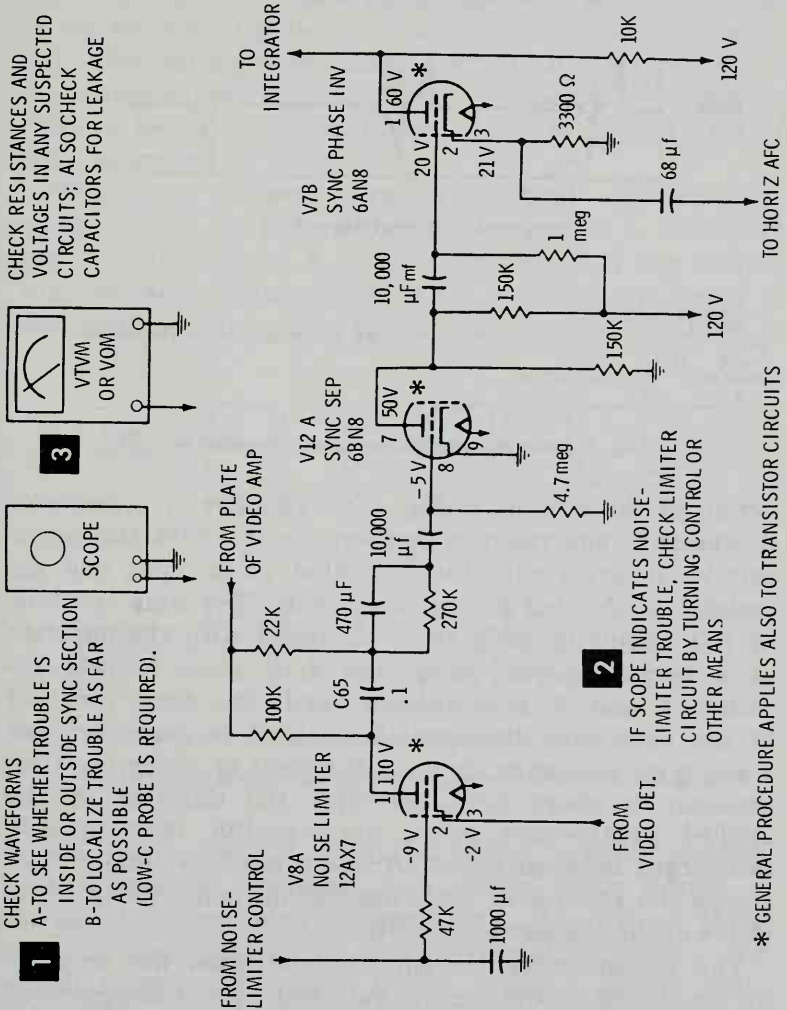
Fig. 8. Preliminary analysis of trouble symptoms in the sync section.

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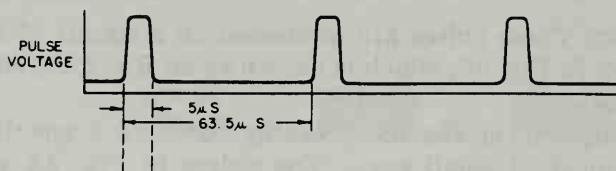
(A) Horizontal sync pulses.
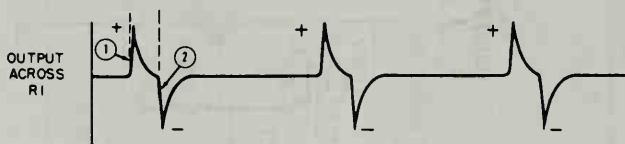
(B) Output of differentiating circuit.
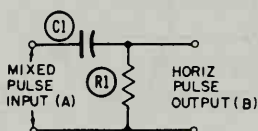
(C) R-C circuit for horizontal separation.

Fig. 9. Horizontal-pulse separation, or differentiation.

action of the circuit in Fig. 19C. The circuit consists of a capacitive and resistive combination in which the capacitor is in series with the separated pulse input and the resistor is shunted across the output. The time constant of this circuit is made short compared with the duration of a horizontal-sync pulse. The sync pulse is held between 4 and 5 microseconds, and the time constant of the horizontal differentiating circuit is made between 1 and 2 microseconds. In an R-C circuit in which the time constant is short compared with the duration of the applied square-wave pulse, the capacitor is completely discharged between pulses. A sharp pip of voltage occurs across the resistor at both the leading and trailing edges of the applied square-wave pulse.

The amplitude of the pip is determined not only by the amplitude of the square wave but by the steepness of the edge of the square wave. For this reason, the FCC

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limits the allowable slope of the leading and trailing edges. These slopes must not occupy more than 0.4 per cent of the horizontal-line scanning interval of 63.5 microseconds.

The voltage pip due to the leading edge of the horizontal-synchronizing square wave is shown as a positive pip at (1) in Fig. 9B. The dip due to the trailing edge of the horizontal pulse is shown as a negative voltage at (2). The leading-edge pulses are the ones which control the horizontal-scanning oscillator. The negative pulses are rejected by cutoff or saturation of one or more stages of the sync system.

When the longer duration vertical synchronizing pulses arrive, the differentiating circuit acts as shown in Fig. 10. Here again, a positive pip occurs at the leading edge of each vertical pulse, and a negative pip occurs at the trailing edge. The leading-edge pulses continue to

(A) Vertical-sync pulse with serrations.

(B) Output of horizontal-differentiating circuit.
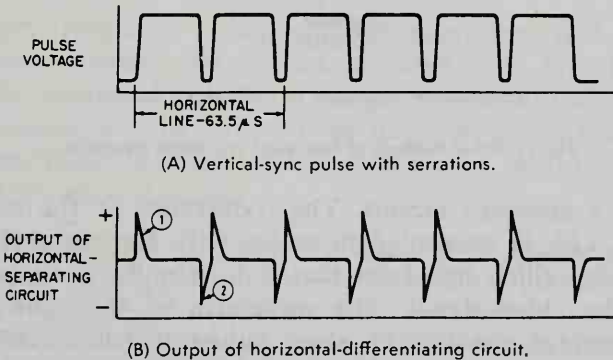
Fig. 10. Action of horizontal-differentiating circuit on vertical-sync signal.

control the horizontal oscillator during vertical retrace. In this instance, however, two pulses occur during a horizontal line-scanning interval. Only the first of these pulses is used to control the horizontal oscillator. The second pulse cannot cause lock-in, since it occurs while the oscillator is insensitive to tripping.

The horizontal pulses can be separated by other means than the R-C differentiating circuit just described. Fig. 11 shows two types of differentiating circuits which employ inductance and a third type which uses the proper-
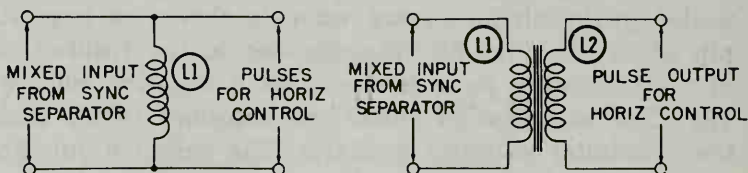
(A) Differentiation by self-inductance. (B) Differentiation by mutual inductance.
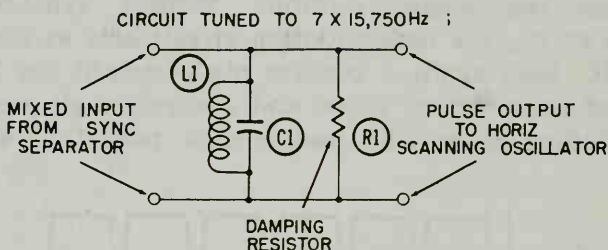
(C) Horizontal separation by tuned-circuit action.

Fig. 11. Other methods of horizontal sync-pulse separation.

ties of a resonant circuit. The inductance of the circuit in Fig. 11A is connected in series with the plate circuit of a tube which has been biased to clip the sync pulses from the video signal. The waveform of the sync-pulse plate current consists of steep slopes which correspond to very rapid changes of current. The voltage across the inductance is proportional to the rate of change of the current through it. Thus, at the leading and trailing edges of each current pulse, a high voltage is produced across the inductor. This voltage is the same form shown for the R-C type of differentiator (Fig. 9B). If the pulses are of proper polarity and sufficient amplitude, they can be applied directly to the scanning generator by a capacitor connected to the plate end of the inductor. If the polarity is incorrect,

phase reversal can be accomplished by an amplifier stage or by a transformer, as shown in Fig. 11B. When a transformer is used, secondary L2 may be connected so that the output voltage pulses have opposite polarity to those across primary L1. The secondary can be connected directly to the input circuit of the horizontal-scanning generator.

The circuit shown in Fig. 11C operates quite differently from the two just described. The resonant circuit, consisting of L1 and C1, is tuned to approximately seven times the horizontal-line frequency of 15,750 Hertz, or 110 kilohertz. The separated sync pulses are impressed across the circuit and shock-excite it into oscillation at its resonant frequency. The oscillation is quickly damped out by parallel resistor R1. Only the first half-cycle of voltage across the circuit is used to control the horizontal-scanning oscillator. This corresponds to a pulse duration of approximately 5 microseconds. Several advantages can be cited for this method of horizontal-sync discrimination:

1. An extremely simple pulse-separation and oscillator-control system can be used. The circuit can be connected directly in the plate return of the sync-separator tube and coupled directly to the scanning oscillator because pulse shaping is performed by the resonant action.

2. This method is relatively immune to excitation by static or ignition noise because such pulses would have to be of the proper time duration (5 microseconds) and repetition rate (15,750 Hertz) to produce ringing. The probability of such coincidence is slight.

Vertical-Pulse Separation—In the description of vertical-scanning systems, we mentioned integrating networks for segregating the long-time vertical field pulses from the sharp horizontal line pulses. We will now consider the means of sorting these vertical field-scanning pulses

(A) Vertical sync-pulse group.
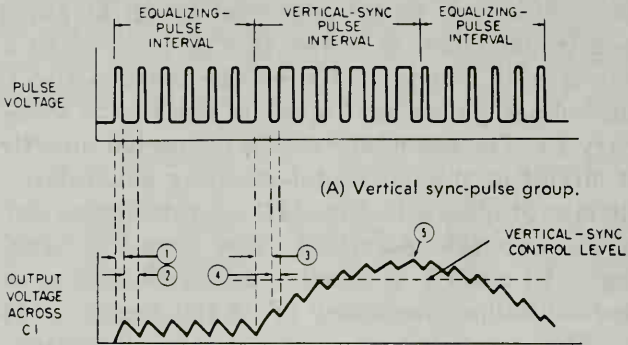
(B) Output of integrating circuit.
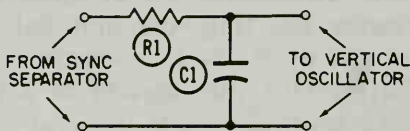
(C) Integrating circuit.
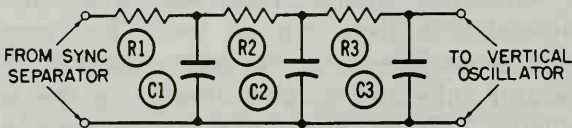
(D) Cascade integrating circuit.

(E) Oscilloscope display of typical integrator output waveform.
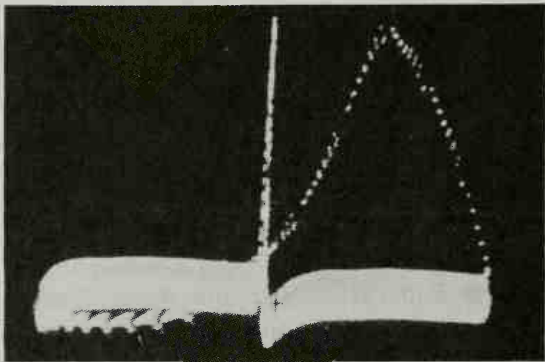
Fig. 12. Vertical-pulse separation by integration.

from the composite scanning pulses and of using them to control the vertical-oscillator timing.

The integrating action which sorts the vertical pulses from the complex video signal is exactly opposite from the differentiation process for separating the horizontal pulses. Integration means the addition of a number of small elements to form a whole. Fig. 12C shows an integrating circuit. It is the opposite of the differentiation circuit in Fig. 9. The resistor is in series with the input, and the capacitor is connected across the output. The time constant of the combination is much longer than that employed for sorting the horizontal pulses. This time constant is made approximately equal to the duration of a horizontal pulse. Consequently, the charge accumulated by the capacitor because of a horizontal pulse is small and will decay rapidly. This action is shown in Fig. 12B. During the time shown at (1), the equalizing pulses produce only a small voltage across the capacitor. This voltage decays to near zero in the interval between pulses, as shown at (2). The much longer vertical-synchronizing pulses produce a greater charge in the capacitor during period (3). This charge does not completely decay during the short serration interval (4). Consequently, each vertical pulse adds an element of charge to the capacitor, and the voltage continues to build up during the interval of vertical pulses. The dotted line in Fig. 12B indicates the level at which this voltage becomes large enough to trigger the vertical-scanning oscillator. This point usually occurs after two or three vertical pulses have charged the capacitor.

The vertical-integrating network is seldom the two-element type shown in Fig. 12C, but is usually a cascade network, as shown in Fig. 12D. The resultant time constant of this network is smaller than that of any of the individual branches (R1-C1, R2-C2, or R3-C3). The overall time constant calculation is the same as for resistors in parallel. For the three-branch circuit in Fig. 12D with T1 for the time constant R1 $\times$ C1 T2 for R2 $\times$ C2, and T3 for R3 $\times$ C3, the effective circuit time constant (T) will be:

$$\frac{1}{T} = \frac{1}{T1} + \frac{1}{T2} + \frac{1}{T3}$$

Individual time constants for a three-branch circuit in a modern receiver are 30 to 60 microseconds. The effective over-all circuit time constants are, therefore, between 10 and 20 microseconds.

The reasons for using cascaded integrating circuits are:

1. To prevent erratic control of vertical retrace by random noise or static pulses. Before such pulses could control the vertical oscillator, they would have to be comparable in duration and spacing to the vertical-sync pulses.

2. To smooth out the contour of the rising voltage wave (shown in the interval 3 to 5 of Fig. 12D) across the output capacitor. The action is similar to that of the familiar resistance-capacitance, power-supply filter system in which the ripple is reduced by successive stages.

Because of this smoothing action, an individual horizontal pulse cannot cause pairing of lines during retrace. The sections of the cascade network are usually not made with equal time constants. This unbalance prevents accidental triggering by noise pulses.

THE FUNCTION OF
VERTICAL-EQUALIZING PULSES

In Chapter 1 we briefly discussed interlaced scanning, which prevents flicker of the image. For simplicity, the retrace from bottom to top of the picture was shown as a straight line or single jump. Actually, the horizontal oscillator must be kept in step with the transmitter during vertical retrace, which lasts from 1250 to 1400

microseconds (20 to 22 horizontal lines). Fig. 13A shows a simplified version of the downward scanning, in which

FIELD NO 1   HEAVY LINES
FIELD NO 2   LIGHT LINES
HORIZONTAL   RETRACE (BLANKED OUT)   - DOTTED LINES
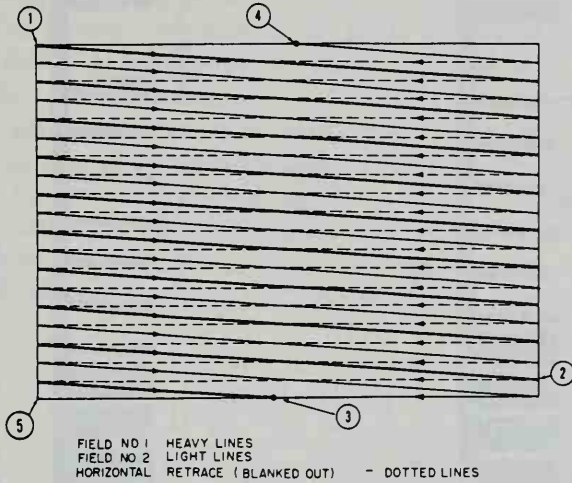
Fig. 13A. Active downward fields.

FIELD 1 RETRACE – HEAVY
FIELD 2 RETRACE – LIGHT
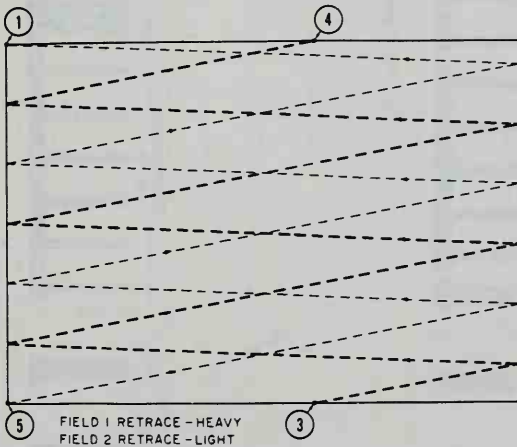
Fig. 13B. Inactive upward fields (vertical retrace).

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Fig. 19C. Vertical-sync signal for retrace after field 1.
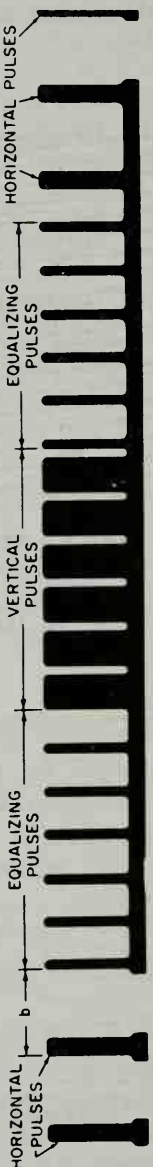
Fig. 13D. Vertical-sync signal for retrace after field 2.

nine and one-half lines have been drawn to represent each field. Actually, a field consists of 262½ lines, less the lines lost during retrace. The first field, which starts at the upper left-hand corner (Point 1) and ends at the bottom center of the picture (Point 3), is shown by heavy lines. The second, or interlaced field, starts at the top center (Point 4) and ends at the lower left-hand corner (Point 5), and is shown by light lines. During vertical retrace, when the picture is blanked out, the beam moves upward under the combined action of both the vertical- and the horizontal-deflection systems. This is represented in simplified form by the diagram in Fig. 13B. Here, three lines represent the twenty to twenty-two lines actually required during vertical retrace. Again, a heavy dotted
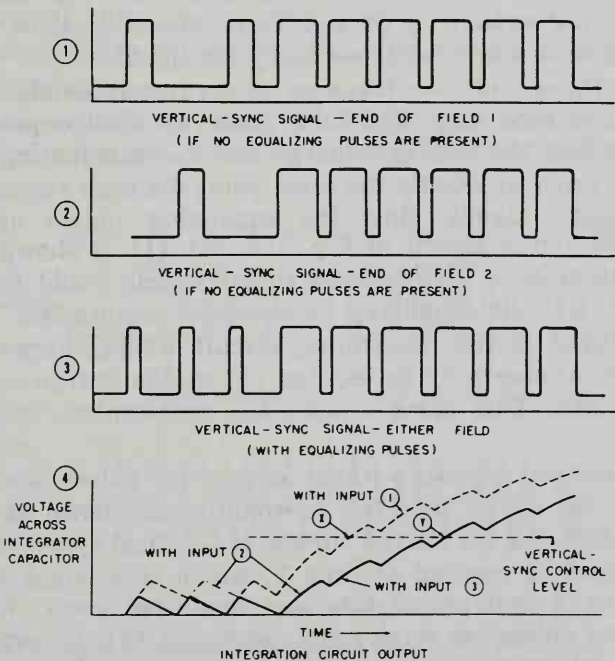
Fig. 13E. Action of vertical-integrating circuit for successive fields (with and without equalizing pulses).

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line represents the retrace of field No. 1, and a light dotted line the retrace of field No. 2.

The dual functions of producing vertical retrace at the proper instant and of keeping the horizontal oscillator in synchronism are controlled by the equalizing and vertical pulses shown in Figs. 13C and 13D. The vertical sync signal for the retrace of field No. 1 differs from that of field No. 2 by the spacing between the last horizontal pulse and the first equalizing pulse. In Fig. 13C for field No. 1, this space (a) consists of only one-half of a horizontal line, since field No. 1 ends at the middle of the last line, as shown at Point 3 of Fig. 13A. In Fig. 13D for field No. 2, the space (b) between the last horizontal pulse and the first equalizing pulse consists of an entire horizontal line. Vertical blanking starts at the leading edge of the equalizing pulses. Thus, the successive field blanking time is accurately set up by the signal.

Even though retrace blanking is accurately established, vertical retrace may not take place at the proper instant unless the critical charge on the integrating capacitor occurs at exactly the same point for each successive vertical-sync signal. How the equalizing pulses assure this condition is shown in Fig. 13E. At (1) is shown the composition of a vertical-sync signal which would follow field No. 1 if the equalizing pulses were not present. This signal input to the integrating circuit would charge the capacitor as shown by dotted line (1) on the charge curves of Fig. 13E. This curve crosses the sync-control level at time X.

The vertical signal, without equalizing pulses, for retrace at the end of field No. 2, would be as shown at (2) in Fig. 13E. On the charge curves, the critical sync-control level would be reached at time Y, which is so much later than time X that proper interlace would not occur. When equalizing pulses are employed as shown at (3), the critical firing point for the vertical oscillator is at time Y for both fields. Successive fields preceded by equalizing pulses will therefore accurately control the oscillator and assure proper interlace.

ACTION OF THE
HORIZONTAL-DIFFERENTIATING CIRCUIT
DURING THE VERTICAL PULSE

The formation of positive and negative pips at the leading and trailing edges, respectively, of the vertical sync pulses was described briefly. We will now consider in detail the action of the horizontal-differentiating circuit during the entire vertical pulse. Fig. 14A shows the pattern of the vertical signal following field No. 2.

The horizontal pulse which starts retrace of the bottom line of the picture is shown at (1) in Fig. 14A. The positive output pip produced by its leading edge is shown at (a) in Fig. 14B. The pips produced by the trailing edge of this horizontal pulse and of all the other pulses of the period (labeled c) are rejected by the sync system, as previously explained.

Each equalizing pulse (2 and 3) before and after the vertical pulse also produces a pair of positive and negative
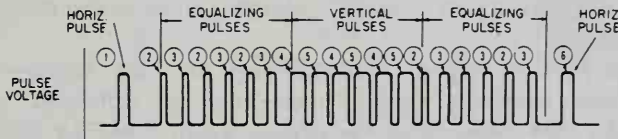
(A) Vertical-pulse group following field 2.
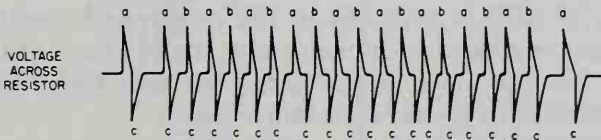
(B) Output of horizontal-differentiating circuit.

Fig. 14. Action of horizontal differentiating circuit during vertical-pulse period.

pips. Only the pips marked (a) are used for oscillator control. Those labeled (b) are rejected, since they occur

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in the scanning cycle, while the horizontal oscillator is not sensitive to pulse control.

Each pulse of the vertical group (4 and 5) also produces a pair of positive and negative pips. However, only the positive pips (a) of Fig. 14B are used. The horizontal pulse shown at (6) is one of a group occurring during the blanking period. The pips produced by the pulse at 6 are the same as those produced by horizontal pulse (1).

It is evident that the vertical-pulse group, because of the individual pulses and their different lengths, can assure vertical retrace at the proper time and keep the horizontal oscillator in step with the scanning in the camera tube at the transmitter.

AGC CIRCUITS

Automatic gain control (AGC) miminizes the effect of changes in signal strength at the receiver antenna. The gains of the RF and IF stages are so regulated that a strong signal is amplified less than a weak signal. As a result, the quality of the TV picture tends to be relatively constant.

Variations in signal strength are of two types— (1) variations between signals received on different channels, and (2) variations occurring from time to time on the same channel.

Both strong and weak channels are available in many locations. If AGC is provided in the receiver, the contrast control does not need to be reset each time a new channel is tuned in. AGC also compensates for extremely strong signals received in powerful station areas.

The AGC system levels out most of the periodic amplitude variations which would cause fading on a particular channel; therefore, a steady picture is obtained, even in moderate fringe areas. The rapid flutter caused by airplanes flying near the path of the transmitted signal is also corrected as much as possible through AGC action.
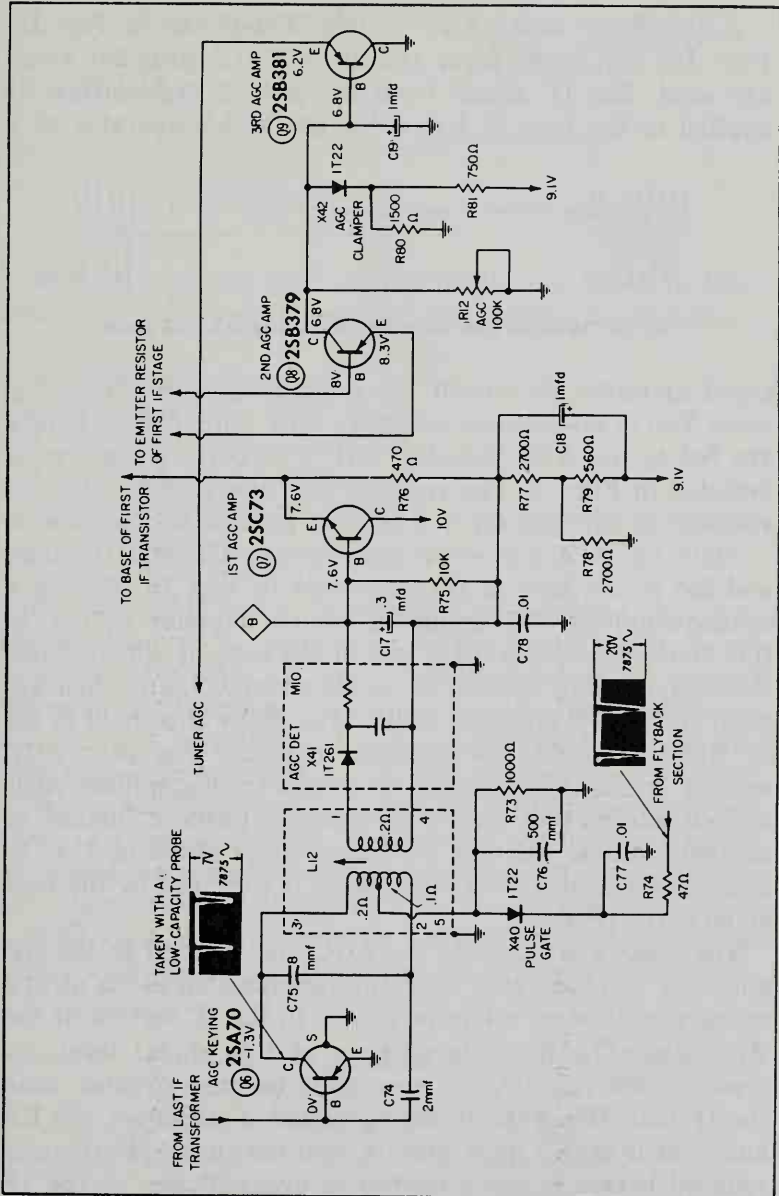
Fig. 15. A transistor keyed—AGC system.

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A transistor keyed-AGC system is depicted in Fig. 15. Four DC amplifier stages and an AGC IF amplifier stage are used. The IF signal from the last IF transformer is applied to the base of transistor Q6, which operates as a

Fig. 16. The output from Q6 in Fig. 15 is a train of pulsed bursts.

keyed amplifier. A 20-volt p-p pulse is applied via gating diode X40 to the collector of Q6. In turn, amplified IF bursts are fed to the AGC detector X41. The burst waveform is depicted in Fig. 16. The rectified and filtered DC output is stepped up through Q7 and is then applied to the base of

Thus, the AGC current is amplified by the first IF stage and fed to the base of transistor Q8 in Fig. 15. This is a common-emitter DC amplifier, which supplies output to the AGC delay diode X42, and to the base of Q9. In turn, the delayed AGC current is amplified by Q9, and then applied to the RF amplifier stage. The delay threshold is set by R12 in Fig. 15. We recognize that the transistor AGC system is basically similar to a tube-type amplifier AGC system, except that control current is processed instead of control voltage. Another difference to be noted in Fig. 15 is that part of the DC amplification is provided by the first stage in the IF strip.

The delay circuit holds the AGC bias applied to the RF amplifier to about zero until the incoming signal is strong enough to develop −4 volts of bias in the IF section of the AGC line. The RF bias appears at this signal level, increases more rapidly, and eventually becomes greater, than the IF bias. When the incoming signal is strongest, the RF amplifier is biased most heavily, and the signal is promptly reduced before it has a chance to overload any of the IF amplifiers.
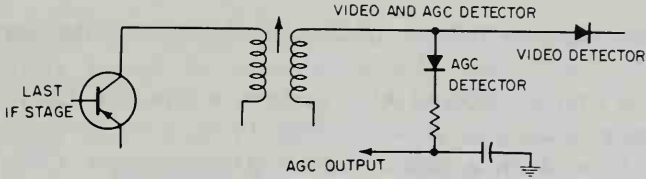
Fig. 17. AGC takeoff from secondary of last IF transformer.

Various types of AGC arrangements are found in transistor TV receivers. These may be classified as follows:

1. Unkeyed reverse AGC.
2. Keyed reverse AGC.
3. Unkeyed forward AGC.
4. Keyed forward AGC.
5. Amplified AGC (used with any of the foregoing arrangements).

Reverse AGC action is obtained by reducing the base-emitter bias on a transistor. As the cutoff point is approached, the gain of the transistor decreases rapidly. Forward AGC action is obtained by reducing the collector voltage on a transistor; this is accomplished by inserting substantial series resistance in the collector circuit. Then, when the AGC bias causes the emitter to draw more current, there is a greater voltage drop across the collector resistance, and the collector voltage decreases. As the saturation point is approached, the gain of the transistors decreases to a small value. Mesa transistors provide better AGC control action with reverse AGC; on the other hand, MADT tran-
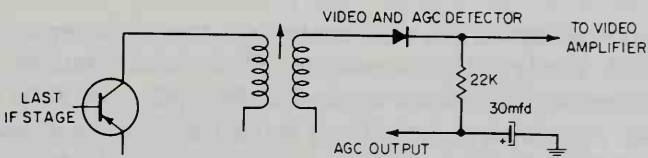
Fig. 18. A single diode may operate as both a video detector and an AGC detector.

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sistors provide better AGC control action with forward AGC.

In a simple unkeyed AGC system, a separate AGC detector may be used, as shown in Fig. 17, or, a single diode may operate as both a video and an AGC detector (Fig. 18). To obtain a wide control range, this system must be followed by an AGC amplifier. We will find that an IF transistor may do double duty as a common-emitter IF signal amplifier, and as a common-collector DC current amplifier for the AGC system. In any case, we usually find a supplementary AGC amplifier employed, as depicted in Fig. 19. A common-emitter DC amplifier is followed by an emitter-follower amplifier. The emitter follower matches the comparatively high impedance of the AGC input circuit to the relatively low impedance of the AGC output bus.

A typical keyed-AGC system is shown in Fig. 20. Q7 is an AGC amplifier which operates at the IF frequency. Note that Q7 is keyed by a pulse from the flyback section, so
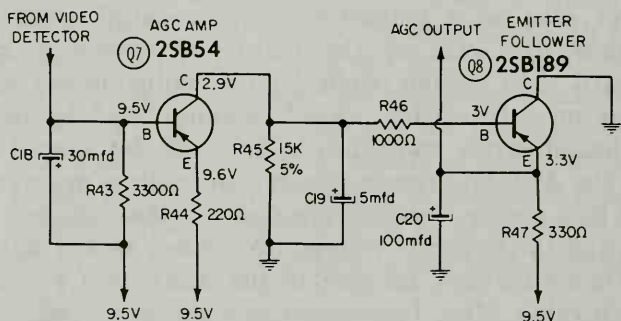
Fig. 19. An AGC amplifier configuration.

that conduction occurs only during the horizontal sync-pulse interval. Diode OA90 is a keying diode which insures that only negative pulses are applied to the collector of Q7. The output waveform is a train of pulsed bursts, as shown in Fig. 16. This burst sequence is rectified by diode M7, which develops a negative DC voltage across C79. Filtering is

provided by C79, R62, and C80. In turn, the base of Q8 is negatively biased in accordance with the prevailing IF signal level.
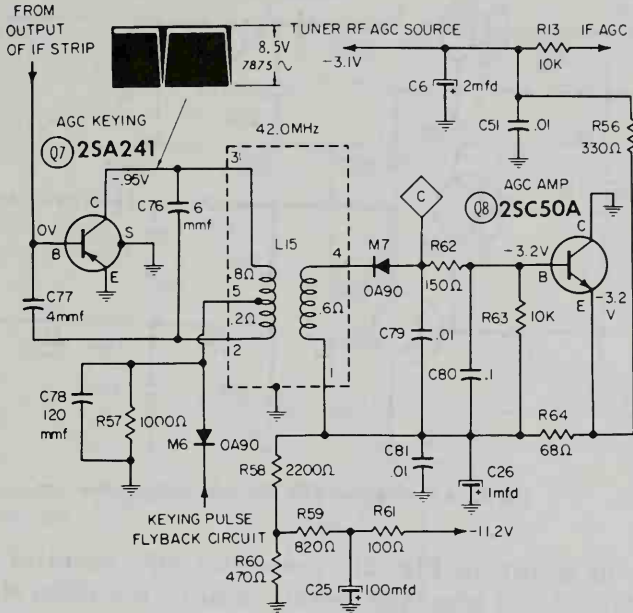
Fig. 20. A typical keyed—AGC system.

Transistor Q8 operates as an emitter follower in Fig. 20, in order to match the comparatively high impedance of M7 to the relatively low-impedance AGC line. Note that Q7 also operates as a DC current amplifier; when a fairly strong IF signal is applied to the base of Q7, the collector voltage changes very little, because the keying pulse drives the transistor into saturation. However, DC amplification is obtained because the IF signal increases the emitter current. The control range of an amplified AGC system is typically 25 db at each AGC-controlled IF stage.

Combination AGC and sync arrangements are used in some receivers. The first stage operates as an emitter fol-

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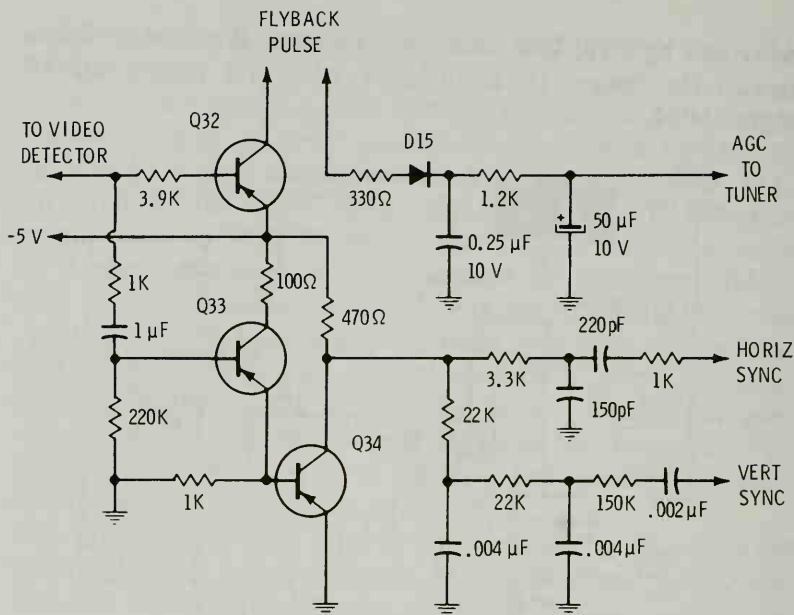
Fig. 21. A combination AGC and sync configuration.

lower, as shown in Fig. 21. Transistor Q33 operates with signal-developed bias, and rejects most of the video signal. Q34 is DC-coupled to the emitter of Q33, and is reverse-biased. No polarity reversal occurs in this circuit from the base of Q33 to the base of Q34. Since Q34 operates at a comparatively low collector voltage, the sync signal is clipped both by reverse bias and by collector saturation. Q34 operates in a common-emitter configuration. Separation of horizontal- and vertical-sync pulses takes place in the branch circuits connected to the collector of Q34. These branch circuits have differentiating and integrating circuits, respectively.

Horizontal-sync pulses are processed in the network comprising the 3.3K resistor, 220 pF capacitor, and 1K resistor. The horizontal sync pulses are fed into a resistive load (not shown in the diagram), so that the 220-pF capacitor forms a differentiating circuit. Note that this differentiator is pre-
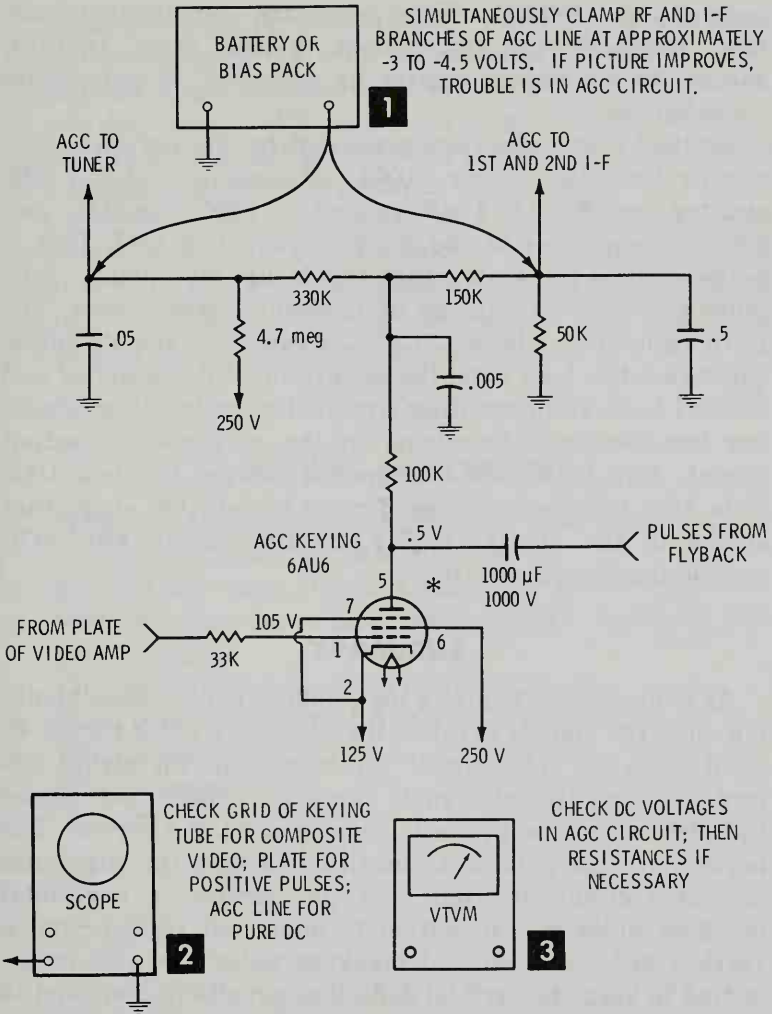
Fig. 22. Basic keyed-AGC troubleshooting procedure.

ceded by an RC integrator comprising the 3.3K resistor and 150-pF capacitor. This integrator has a time constant of approximately 0.5 μs, and helps to minimize noise voltages by reducing the circuit bandwidth as much as is practical. The highest frequency of importance in a horizontal sync

pulse is about 150 kHz. Noise pulses are comparatively narrow, compared with sync pulses, in most cases. In turn, bandwidth restriction assists in reduction of noise-pulse disturbances.

Vertical sync pulses are processed by the network comprising the 22K resistor, 0.004 μF capacitor, second 22K resistor, second 0.004 μF capacitor, 150K resistor, and 0.002 μF capacitor in the collector circuit of Q34. This is a two-section integrator that builds up the vertical sync pulse and opposes passage of horizontal sync pulses. The 150K resistor isolates the 0.002 μF capacitor and its subsequent resistive load from the integrator. This capacitor and its load form an integrating circuit that assists in minimizing low-frequency transients in the vertical-sync output circuit. AGC voltage to the tuner is delayed by diode D15. This AGC voltage is derived from a keyed-AGC stage (not shown in the diagram). Fig. 22 illustrates basic AGC troubleshooting procedure.

SUMMARY

As indicated in Chapter 1 the combination of video, blanking and sync signals is called the *composite video signal*. In addition to the video signal which contains the actual picture, four additional signals must be transmitted before the picture can be properly displayed on the screen. The horizontal sync pulse is transmitted to keep the horizontal deflection circuit in step with the picture; a horizontal blanking pulse is transmitted to blank out retrace, and a vertical sync and vertical blanking pulse are also transmitted to keep the vertical deflection circuits in step, and to blank the beam when it is returning from bottom to top.

The pulses occur when the electron beam in the picture tube is cut off. The pulses can be clipped from the signal at three different places in the circuit. This can occur at the video detector input, at the video amplifying stages, or at the point of restoration of the average background light of the picture.

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Some television receivers employ more than a one-stage circuit to separate the sync pulses from the video signal. Additional stages are used to invert the phase of the pulses, to clip the pulse width, to amplify the pulse, to level the pulse, and to eliminate noise pulses to minimize interruption of sync and tearing of the picture.

Automatic gain control (AGC) is used to minimize the effect of changes in signal strength at the receiver. The gains of the RF and IF stages are so regulated that a strong signal is amplified less than a weak signal. As a result, the TV picture tends to be relatively constant.

REVIEW QUESTIONS

1. Why is a transistor amplifier with base input and collector output called a phase inverter?
2. Explain the basic clipper circuit.
3. Why are transistors more efficient than diodes in clipper circuits?
4. Why is interlaced scanning used?
5. What is the definition of AGC?
6. What is delayed AGC?
7. What is keyed AGC?

CHAPTER 11

Deflection Circuits

Television receivers have generally employed three types
of circuit arrangements, or combinations of these circuits,
to produce sawtooth waveforms for scanning purposes.

1. *The multivibrator.* This circuit arrangement has many
   variations. The most popular variation is shown in
   Fig. 1.
2. *The blocking oscillator.* This type of circuit permits
   the formation of a short pulse of energy. This pulse
   can be used to produce the sawtooth wave across a
   capacitor directly associated with the oscillator de-
   vice, or the pulse can trigger a discharge device which
   acts as a switch across the capacitor. (See Fig. 2).
3. *The sine-wave oscillator.* An oscillator of the correct
   frequency supplies the timing voltage for the dis-
   charge device. The sine-wave output of this oscillator
   is modified into short pulses by wave-shaping circuits.
   These pulses then operate a discharge device to pro-
   duce sawtooth waves.

SAWTOOTH GENERATION

A sawtooth waveform is the basic deflection waveform.
A sawtooth waveform can be generated in a suitable modi-
fied blocking-oscillator configuration, as shown in Fig. 3.

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(A) Schematic.
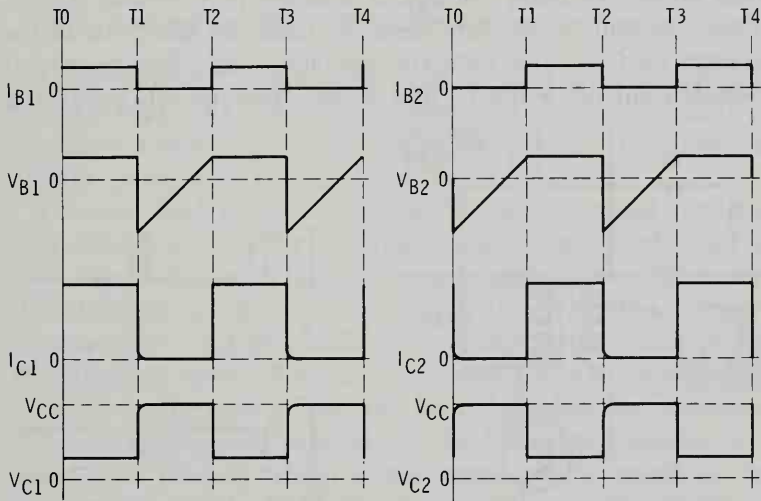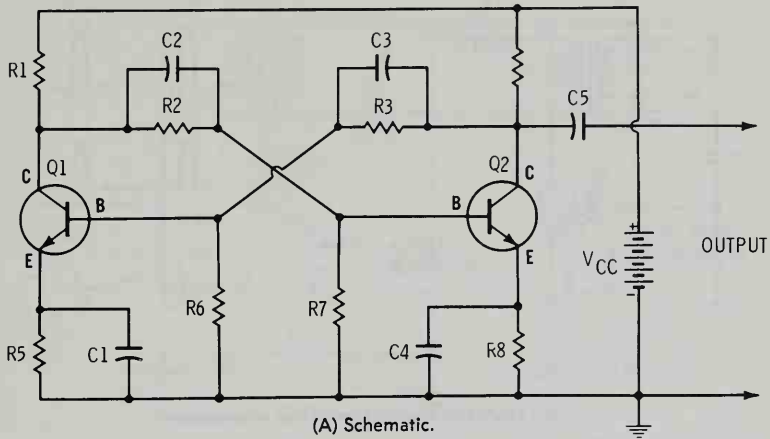
(B) Waveforms.

Fig. 1. Transistor multivibrator arrangement.

Circuit action occurs as follows: As transistor Q conducts, capacitor C_s charges toward the bias voltage level. As collector current flows, a transient voltage is induced into the base circuit by transformer T. The base is driven more negative, and the transistor is driven rapidly into saturation. At this instant, C_s is fully charged, and flow of collector cur-

(A) Schematic.

(B) Waveform.
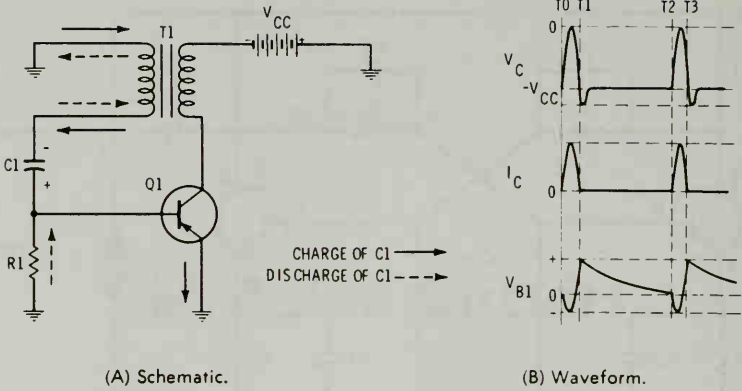
Fig. 2. Transistor blocking oscillator arrangement.

rent stops. No more voltage is induced in the base circuit. Thus, the emitter is more negative than the base, due to the charge on C_s, which cuts the transistor off. The transistor remains cut off while C_s discharges through R_s, producing
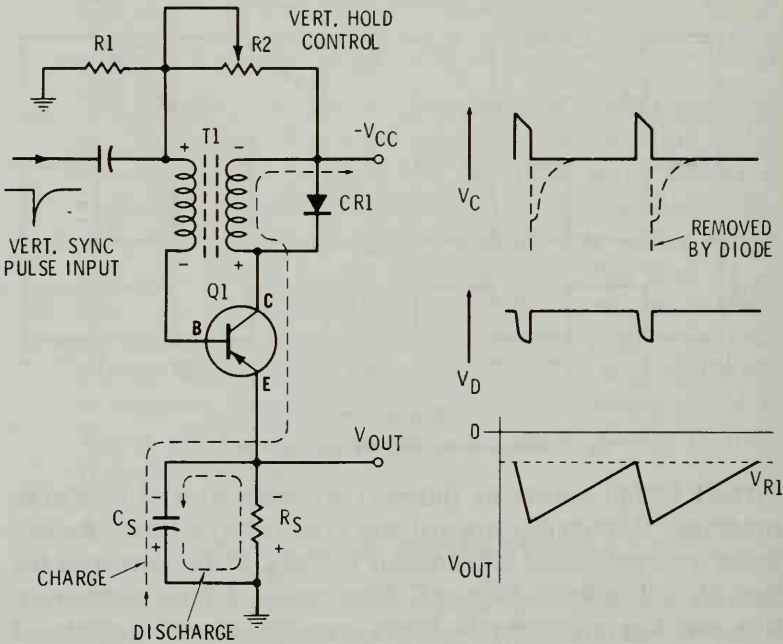
Fig. 3. A sawtooth generating circuit of the blocking-oscillator type.
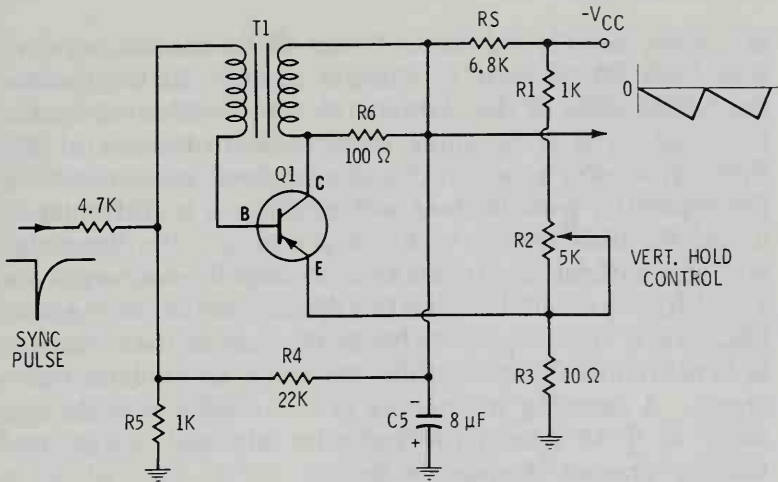
Fig. 4. A sawtooth waveform generator that provides a negative-going output.

the rising slope of a sawtooth wave. When C_s discharges sufficiently that the transistor comes out of cutoff, positive feedback action starts up once more, thereby forming the flyback portion of the sawtooth wave.

Observe that the vertical sync pulse is coupled into the base circuit of Q in Fig. 3. Since R2 is normally adjusted so that the blocking oscillator has a slightly lower frequency than the sync-pulse repetition rate, the sync pulse triggers the transistor out of cutoff sooner than would occur in the free-running mode of operation. Thereby, the sawtooth oscillator is synchronized. Resistor R2 establishes the oscillator frequency because it determines the bias level, and in turn selects the time at which Q will come out of cutoff in the free-running mode. Diode X is a protective device connected across the primary of T to dissipate the inductive kickback surge which would otherwise cause transistor breakdown. The waveform V_{R1} is described as a positive-going sawtooth because it rises from a more negative value to a less negative value.

Some designs require a negative-going sawtooth waveform. With reference to Fig. 4, C_s is uncharged at the time that the receiver is turned on. The base voltage on transistor

Q is zero, and the transistor is cut off because of negative bias from R3. In turn, C_s charges through R_s to generate the falling slope of the sawtooth waveform. Meanwhile, the base bias on Q is becoming more negative because of R5. There is a point at which Q suddenly goes into conduction. Consequently, positive feedback action via transformer T drives the base voltage highly negative, and the transistor goes into saturation. At this time, C_s rapidly discharges via T and R_s to ground, forming the flyback portion of the sawtooth wave. A sync pulse is fed to the base of the transistor to synchronize the oscillating frequency, as explained previously. A damping resistor R6 is connected across the primary of T to reduce the inductive kickback surge, and thereby prevent damage to Q.

Next, consider the two transistor peaked-sawtooth multivibrator shown in Fig. 5. This is an example of the trend that has been taking place in the discard of separate oscillator and output stages and adoption of combined transform-
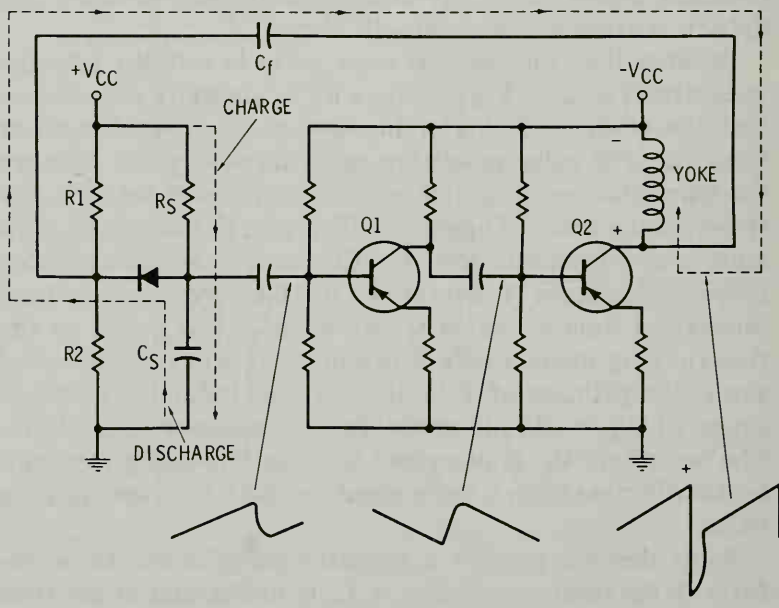
Fig. 5. A multivibrator peaked-sawtooth waveform generator configuration.

DEFLECTION CIRCUITS

erless circuitry in which positive feedback takes place from
the output stage. This circuit uses a common-emitter ar-
rangement for both the input and output transistors. A
diode is used as an electronic switch to charge and discharge
the sweep capacitor in the feedback loop from the output
transistor. Note that the instant that power is turned on to
the circuit, the voltage across the sweep capacitor C_s is
zero. The diode is connected between C_s and a positive bias
voltage that is tapped off at the junction of R1 and R2.
Initially, the diode is reverse-biased, and it isolates the
sweep capacitor from R1 and R2 as well as from the feed-
back circuit via C_f.

While the diode is reverse-biased, C_s charges through
R_s to the value of the applied positive voltage. This rising
positive voltage is applied to Q1 and forms the slope por-
tion of the sawtooth wave. In turn, this rising positive
voltage is applied across the deflection yoke. At the instant
that the charge on C_s equals the voltage across R2, the
diode starts to conduct and the voltage across C_s cannot
increase further. Also, the sweep capacitor is connected
to the feedback loop, and the voltage across the yoke falls
quickly to zero. In other words, a regenerative discharge
cycle starts, in which C_s discharges through the diode, C_f,
and the yoke. A high amplitude negative kickback pulse is
applied to the collector of Q2 at this time, causing C_s to dis-
charge rapidly. Then the yoke voltage starts to swing posi-
tive, the diode cuts off, the feedback loop is disconnected
and C_s starts to charge once more.

A vertical-output circuit is always designed to provide
a retrace blanking pulse for the picture tube. A blanking
pulse of suitable amplitude and polarity is often obtained
from a secondary winding which is wound on the coupling
choke, as depicted in Fig. 6. Thus, the coupling choke has
a transformer construction; it is sometimes called a vertical
output transformer, although it is technically a blanking
transformer and coupling choke. An RC wave-shaping cir-
cuit is used between the transformer and the picture tube
to change the peaked-sawtooth waveform into a pulse train.

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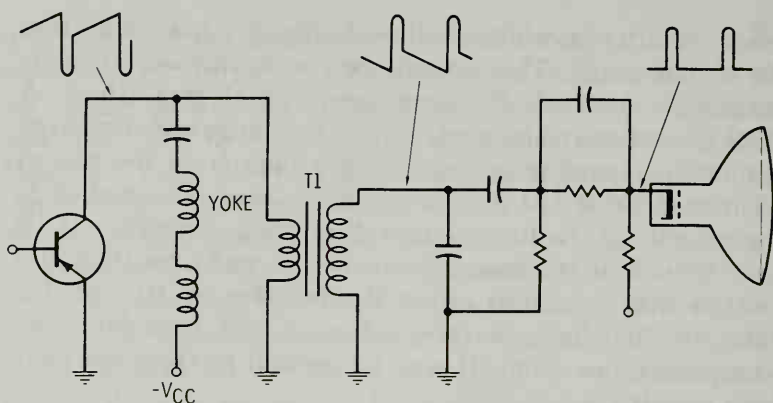
Fig. 6. A typical vertical retrace blanking circuit.

In transistor TV receivers, blocking oscillators are commonly employed in both the vertical and horizontal deflection sections. Fig. 7 shows a typical vertical-oscillator configuration. The tightly coupled windings of transformer T2 provide positive feedback from collector to base of transistor Q14. This transistor operates in Class C and conducts only for brief intervals—that is, the circuit operates as a pulse oscillator. During conduction, the base of Q14 is driven strongly by the amplified output from the collector. The base-emitter junction rectifies these negative-going pulses and charges C21 negatively; after the passage of each pulse, Q14 is cut off, or blocked. Note that Q14 is reverse-biased due to this blocking action.

With the emitter more negative than the base, Q14 (Fig. 7) remains cut off until C21 discharges sufficiently through R79 that the base voltage reaches the conduction level. Then, as Q14 comes out of cutoff, another sudden surge of oscillation occurs, after which Q14 is again blocked. The time at which the transistor comes out of cutoff is adjusted by varying the base bias with control R4. Vertical-hold control R4 is set to a point at which the blocking rate is somewhat slower than 60 Hz. Negative-going vertical-sync pulses are coupled to the base of Q14 via T2. In turn, the sync pulses trigger the blocking oscillator into conduction
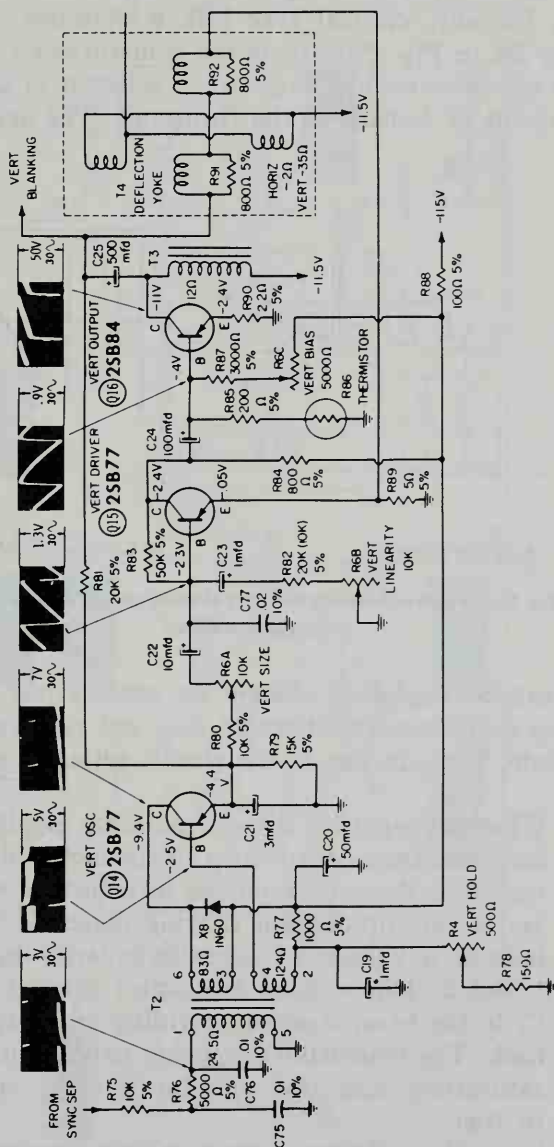
Fig. 7. A typical transistor vertical-sweep system.

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a bit earlier than the stage would otherwise come out of
cutoff. Thereby, vertical sync lock is obtained.

Diode X8 in Fig. 7 prevents the transformer from apply-
ing an excessive peak voltage to the collector of Q14, which
could result in damage to the transistor. The action of the

(A) Circuit schematic.

(B) Collector waveform.
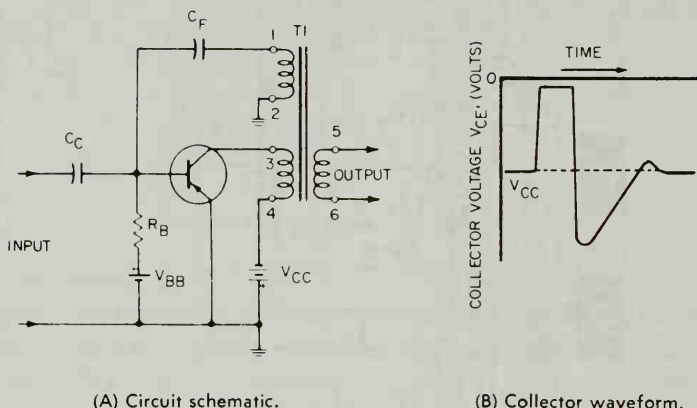
Fig. 8. A triggered blocking oscillator showing the collector-to-emitter
voltage waveform.

diode can be explained clearly by considering a simpler
blocking oscillator circuit which does not require a protec-
tive diode. Thus, in Fig. 8, the circuit action is as follows:

1. When a negative trigger pulse is applied to the
base, the transistor begins to conduct. Collector cur-
rent then flows through the transformer windings 3
and 4, and produces a varying magnetic flux which
induces a voltage of opposite polarity in windings
1 and 2. This voltage is coupled through capacitor
C_F to the base, thereby providing regenerative feed-
back. The transistor is quickly driven into collector
saturation, and the collector current cannot rise
further.

2. Since the collector current is now constant, T1 can
induce no more feedback voltage into the base cir-
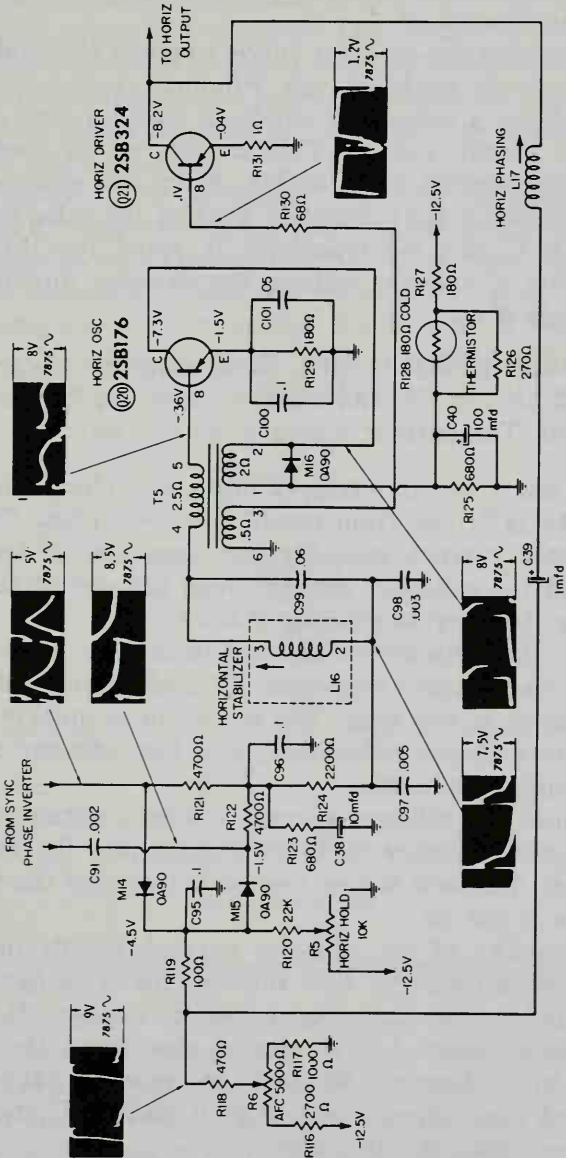
Fig. 9. A typical transistor horizontal-AFC, oscillator, and driver configuration.

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cuit. The base is now reverse-biased, and the tran-
sistor is cut off.

3. Stopping the collector current results in a collapsing
magnetic field through windings 1 and 2, which
induces a voltage in windings 3 and 4 that exceeds
the supply voltage. This is seen as the backswing
following the pulse in Fig. 8. In this example, the
backswing approximately doubles the collector volt-
age. Unless the transistor is rated for this peak
value of collector voltage, the collector junction will
break down.

With these points in mind, let us consider the action of
diode X8 in Fig. 7, and observe how the backswing is
eliminated. The current action is as follows:

1. When a negative trigger pulse is applied, transistor
Q14 is driven from cutoff into conduction. The col-
lector current suddenly increases due to feedback,
and the collector voltage drops because of the volt-
age drop across windings 3 and 6.

2. As the collector voltage suddenly falls, diode X8 is
reverse-biased; therefore, X8 is effectively out of the
circuit at this time. The transistor is quickly driven
into collector saturation, and the collector current
cannot rise further.

3. Since the collector current is now constant, T2 can
induce no more feedback voltage into the base cir-
cuit. The base is now reverse-biased, and the transis-
tor is cut off.

4. Stopping of the collector current results in a col-
lapsing magnetic field through the windings, which
quickly increases the collector voltage. However,
the collector voltage cannot rise above the supply
voltage, because X8 then becomes forward-biased,
and short-circuits windings 3 and 6. Thereby, the
backswing is eliminated.

Next, let us consider a blocking oscillator utilized in a
horizontal-oscillator section. With reference to Fig. 9, tran-

sistor Q20 operates as a blocking oscillator, and the time at which it comes out of cutoff (and hence its repetition rate) depends on the value of base bias voltage. L16 and C99 form a ringing circuit which stabilizes the cutoff point for Q20 by superimposing a sine wave on the blocking-oscillator waveform.

The action of the horizontal stabilizer is seen in Fig. 10. When a ringing coil is not used, the decay of the voltage is exponential and approaches the cutoff level slowly. In turn, the instant at which conduction is initiated can vary appreciably due to slight voltage fluctuations or small noise voltages. On the other hand, when a ringing coil is used, a sine wave is superimposed on the exponential waveform,

(A) Without ringing coil.
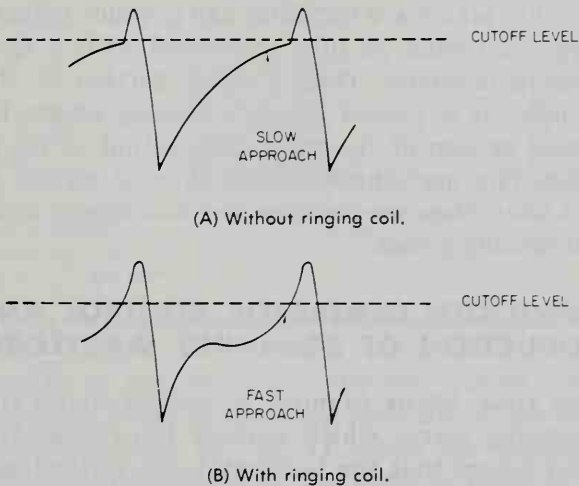
(B) With ringing coil.

Fig. 10. Oscillator waveforms with and without a ringing coil.

and the combined waveform approaches the cutoff level rapidly. Because of the steep slope of the waveform through the conduction level, the instant at which conduction is initiated does not vary to a disturbing extent, even when small noise voltages or other fluctuations are present. Horizontal-stabilizer coil L16 is adjustable so that the optimum phase of ringing waveform can be utilized.

Regenerative feedback occurs from collector to base of Q20 in Fig. 9. This feedback is provided by the tightly coupled windings of transformer T5. In turn, blocking oscillation occurs. Diode M16 short-circuits the backswing of the generated waveform, as explained previously. This prevents excessive peak collector voltage from being applied to Q20. Collector-current stabilization is provided by thermistor R128. If the temperature rises, the resistance of R128 increases, thus reducing the collector voltage and preventing Q20 from drawing increased current from the DC supply.

SINE-WAVE GENERATORS

The familar sine-wave oscillator can produce pulses which will trigger a discharge tube associated with a sawtooth-waveforming capacitor. Only a short portion of the sine wave is used. It is passed through clipping stages to "bite off" a small section of the wave. The output of the clipper is a pulse. The usefulness of this type of circuit will be discussed later when we consider how scanning is controlled by synchronizing pulses.

SAWTOOTH GENERATOR CONTROL AND PRODUCTION OF SCANNING WAVEFORMS

At this time, let us examine in greater detail the sawtooth scanning waves which produce the raster. We have mentioned before that the horizontal and vertical sawtooth motion of the electron beam must keep in step with similar sawtooth scanning movements occurring at practically the same instant in the camera tube at the transmitter.

To accomplish this synchronization, pulses which control the horizontal and vertical scanning are transmitted in the television signal. These pulses occur between each horizontal frame. During the scanning of the frame, the receiver is "on its own." However, during the short interval between successive horizontal frames, the deflection cir-

cuits of the receiver are the absolute "slave" of the trans-
mitter if the set is well designed, operating properly, and
being used in an area of adequate field strength.

How the synchronized pulses are separated from the
complex signal has already been covered. At this point,
we will examine the relationship between the timing of
these pulses and the control of the sawtooth scanning of
the receiver. Fig. 11 shows the sequence of events during
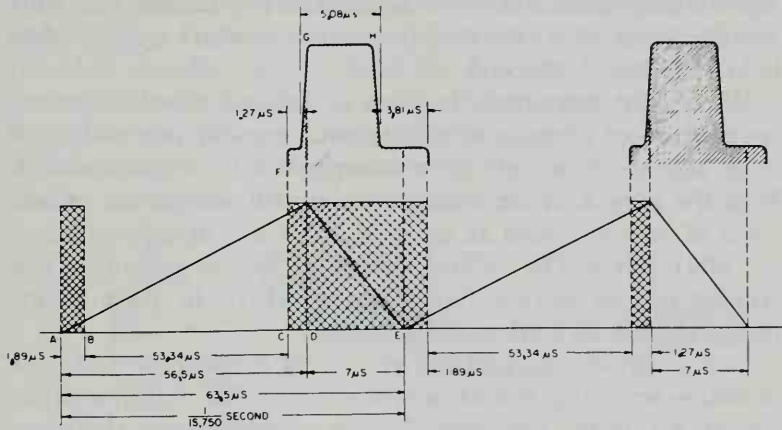
Fig. 11. Horizontal-scanning wave and synchronizing signal.

the scanning of one horizontal line and during the return
of the electron beam to start the scanning of the next line.

The sawtooth line in Fig. 11 shows the desired linear
trace and retrace motions of the electron beam in the TV
picture tube. It does not necessarily depict the exact wave
of current which must be passed through the deflection
coils of the picture tube. As a matter of fact, we will find
later that the deflection current must be distorted some-
what to accomplish the linear sweep and rapid fly-back of
the beam of electrons tracing the picture.

Fig. 11 shows, therefore, the *idea* sawtooth for controlling
the horizontal scanning motion in a television receiver. At
point A, the electron beam starts to cross the face of the

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picture tube horizontally from left to right. We will assume the picture tube is a 17-inch type and has an active picture width of 14 inches. The beam has blanked out from A to B, and the picture starts at point B. Between points B and C as the uniform motion progresses, the video modulation produces the picture.

As we have previously stated, the picture frame consists of 525 horizontal lines reproduced each 1/30th of a second (30 frames per second times 525 lines per frame equals 15,750 horizontal lines per second). This means the time for the trace of a line and its return to start another line is 1/15,750th of a second.

We should introduce the idea of talking about these extremely short time intervals in multiples of one millionth of a second. The unit of measurement is a microsecond. It is the length of time required for the completion of one cycle of carrier wave at the middle of the broadcast band, or 1,000 K Hertz. The entire horizontal action, including the tracing of the picture line and the return to start a new line, occurs in 63.5 microseconds.

Let us divide the picture width (14 inches) by the time of active scanning (53.34 microseconds). We obtain a velocity of 4.1 miles per second. The retrace time (between points D and E in Fig. 11) is 7 microseconds. Since this retrace is over the same 14 inches of horizontal motion, the speed of the spot (blanked out to produce no light) must obviously be much faster. Actually, this retrace can reach a speed of 31.5 miles per second.

As we previously stated, the sequence of events must occur exactly in step with a similar sequence occurring at the same instant in the camera tube at the transmitter. To accomplish this action, pulses are sent out from the transmitter between each horizontal trace. The shape of these pulses is shown above the sawtooth wave in Fig. 11. At the instant shown as F, enough voltage appears at the grid of the picture tube to blank out all light. The region from F to G is known in television slang as the "front porch." This region is slightly more than one-millionth of a second

in duration. At point G, the carrier wave of the transmitter abruptly increases by approximately 25% of its average value. This sharp rise in the carrier triggers the scanning generators in the receiver. The scanning generators produce the required sawtooth motion of the electron beam. Exactly how the pulse accomplishes this triggering will be described later.

The horizontal beam does not trace a line parallel with the top of the picture, but has a slight downward slope. This vertical motion is controlled by a scanning sawtooth which moves the scanning spot to the bottom of the image and then rapidly returns it to the top. The electron beam moves from the top to the bottom of the picture and back to the top in 1/60 of a second. It is easy to see that this vertical scanning is much slower than the horizontal line tracing action and requires 16,666 microseconds. Pulses
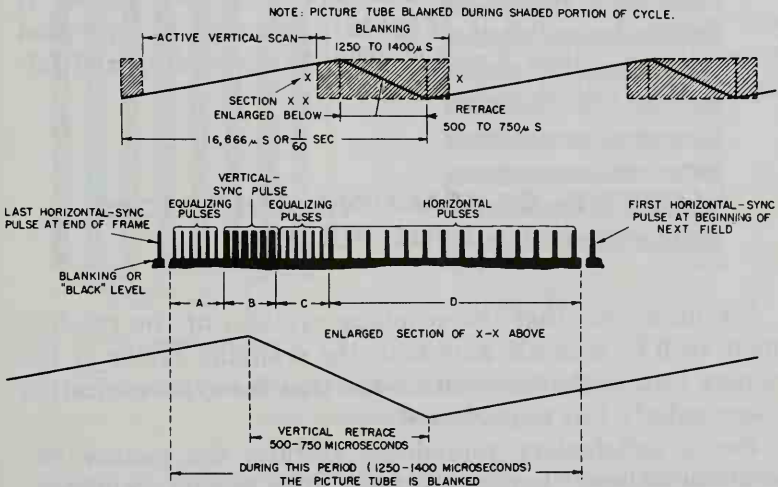
Fig. 12. Vertical-scanning wave and synchronizing signal.

are sent out between successive fields to lock in, or control as a slave, the vertical-scanning oscillator of the receiver. A cycle of the vertical-deflection sawtooth wave, together

with an enlarged section of that part of the wave which occurs during blanking and retrace, is shown in Fig. 12.

The portion of the television signal which controls vertical retrace and synchronization is much more complicated than the single horizontal pulses which occur between successive horizontal lines. The vertical synchronizing signal resembles a comb with uneven teeth. If its only function were to trigger the vertical oscillator and to blank out the picture-tube screen during retrace, it could be made in the form of a single long rectangular pulse whose time duration would be from 20 to 22 horizontal lines (1,250-1,400 microseconds). However, the vertical synchronizing signal must perform two other functions. It must continue to keep the horizontal-scanning oscillator in step during vertical retrace and also assure that alternate fields have proper interlace of the horizontal lines.

Horizontal synchronization is kept in step by notches B and pulses A, C, and D (Fig. 12). Interlace is controlled by equalizing pulses A and C (Fig. 12) preceding and following the vertical sync pulse.

CONTROL OF SCANNING GENERATORS
BY SYNC PULSES

We have seen that the scanning systems of the receiver must keep in accurate step with the scanning raster of the camera tube at the transmitter and that the synchronization pulses satisfy this requirement.

For a satisfactory reproduced picture, the picture elements of adjacent horizontal traces must line up accurately, and the lines of alternate fields must interlace or space accurately between each other.

To avoid a displacement of more than one picture element in successive horizontal lines, the frequency stability of the horizontal oscillator must be 0.2% or better. Fig. 13A illustrates horizontal displacement.

To avoid "pairing" of the lines of successive fields (the line lying on top of those of the preceding field instead of being properly interlaced), the stability of the vertical oscillator must be better than 0.05%. Fig. 13B illustrates this displacement.

IDEAL CONDITION -- PICTURE ELEMENTS ENLARGED

EACH SQUARE REPRESENTS
ONE PICTURE ELEMENT

RESULTING PATTERN -- HORIZONTAL
DISPLACEMENT BY THE WIDTH
OF ONE PICTURE ELEMENT .

(A) Horizontal displacement.

RESULTING PATTERN-- VERTICAL
DISPLACEMENT BY ONE
PICTURE ELEMENT   (PAIRING)

(B) Vertical displacement.
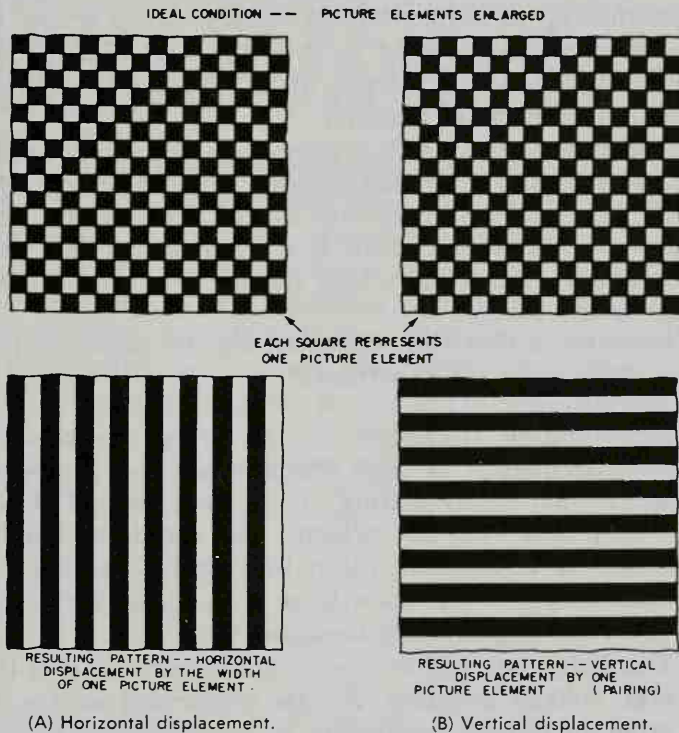
Fig. 13. Picture-element displacement that might result from
scanning-oscillator instability.

Note in passing that there are various receiver sections that are generally associated with the horizontal-output system. As shown in Fig. 14, these sections typically comprise the high-voltage system, the AGC and AFC sections, the horizontal oscillator, the vertical sweep circuit, the yoke, and the picture tube. Thus, the horizontal-output system supplies feedback pulses to the AGC and AFC sections,

boost voltage to the vertical-sweep circuit and horizontal oscillator, high voltage to the picture tube, and horizontal drive to the yoke. The horizontal oscillator supplies a drive signal, and the low-voltage power supply provides (B + (V_{cc}) voltage to the horizontal-output section. When checking the linearity of horizontal and vertical sweep action, an audio oscillator may be used, as shown in Fig. 15. Note the extended high-frequency output, up to 1.5 MHz, is required for checking horizontal linearity.

The horizontal and vertical pulses are clipped from the signal, amplified, and passed through circuits which classify the pulses so that each will control its own scanning oscillator only. The end result is a short, sharp "pip" for the horizontal control and a long triangularly shaped pulse for the vertical control.

In considering how the pulse controls the oscillator frequency, three items are important:

1. Free-running frequency of the sweep generator.—This frequency is that which would be generated at any particular setting of the hold control if the sync pulses were not present. The frequency can be slower or faster than the pulse repetition rate, or in exact step. We will show later that, for proper stable operation, the slow rate is required.

2. The fiiring point of the sweep generator.—This is the bias voltage required for the controlled device in order to initiate conduction in the discharge device, and to start capacitor discharge and scanning-wave retrace. At this point in the cycle the oscillator is most sensitive to control by the sync pulse.

3. The synchronizing frequency.—This is the rate at which the pulses are applied to the control-input terminal of the oscillator—60 Hertz for vertical synchronization and 15,750 Hertz for horizontal synchronization.

Since the control action of the blocking oscillator can be more readily diagrammed, we will consider it first.

Pulse Control of the
Vertical Blocking Oscillator

The triggering, or firing, of the blocking oscillator occurs when the bias voltage passes the cutoff point. The free-running frequency of the oscillator (if no sync pulses are present) is determined solely by the time constant of the base capacitance and resistance. Once the oscillator is fired, it functions on its own until it is blocked again by the base cutoff voltage.

If a pulse of positive potential from an external source is fed to the base while the base capacitor is discharging through the resistor, the base voltage will pass the cutoff point, and the device will begin to conduct. The sawtooth-forming capacitor will discharge, and retrace will occur. A new scanning cycle then begins. Therefore, the repetition of the positive sync pulses can control the firing of the blocking oscillator and lock the picture into synchronization.
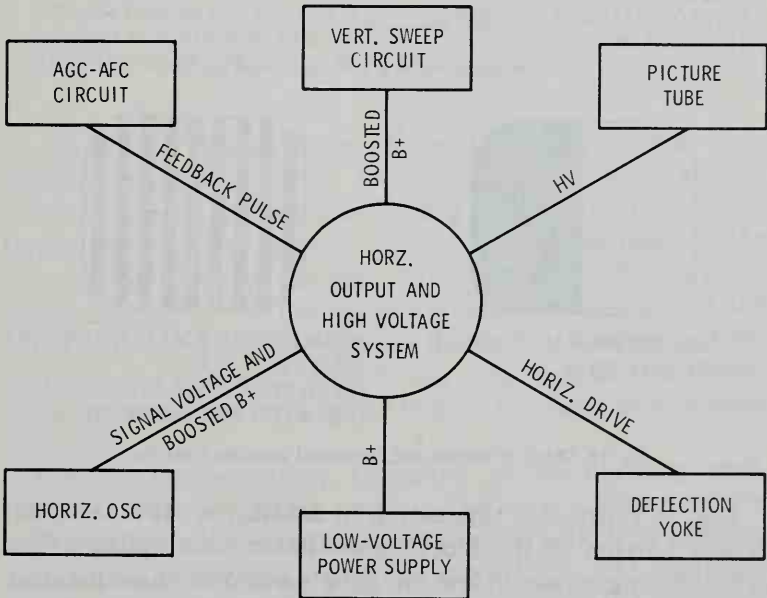
Fig. 14. Some of the circuits commonly associated with the horizontal output and high voltage system.
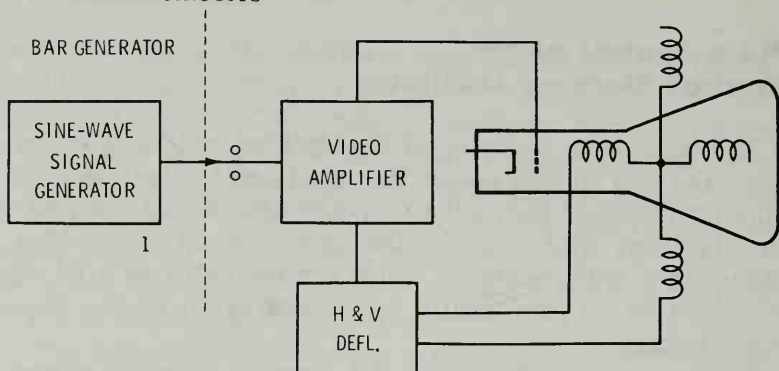
SIGNAL GENERATOR SET TO EQUAL V
SWEEP OSCILLATOR FREE-RUNNING
FREQUENCY (60 Hz).

SIGNAL GENERATOR AT MULTIPLE OF 60Hz
CREATES HORIZONTAL BARS SUITABLE
FOR CHECKING VERTICAL SCANNING
LINEARITY OF MASTER MONITOR SWEEP.
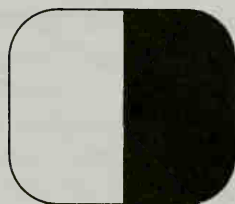
SIGNAL GENERATOR SET TO EQUAL H
SWEEP OF 15, 750 Hz.
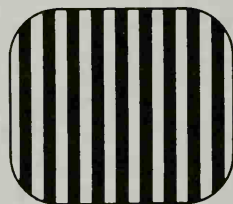
SIGNAL GENERATOR SET AT MULTIPLE OF H
SWEEP OSCILLATOR.
FOR CHECKING HORIZONTAL SWEEP
LINEARITY OF MASTER MONITOR.

Fig. 15. Check of vertical and horizontal scanning linearity.

Fig. 16 illustrates this action in detail. Fig. 16A is an en-
larged portion of the blocking-oscillator base voltage. The
synchonizing pulses below the base waveform show a series
of pulses marked "O" whose leading edges are exactly in

(A) Grid-voltage waveform with a series of sync pulses.

(B) Oscillator frequency fast.

(C) Oscillator frequency slow.
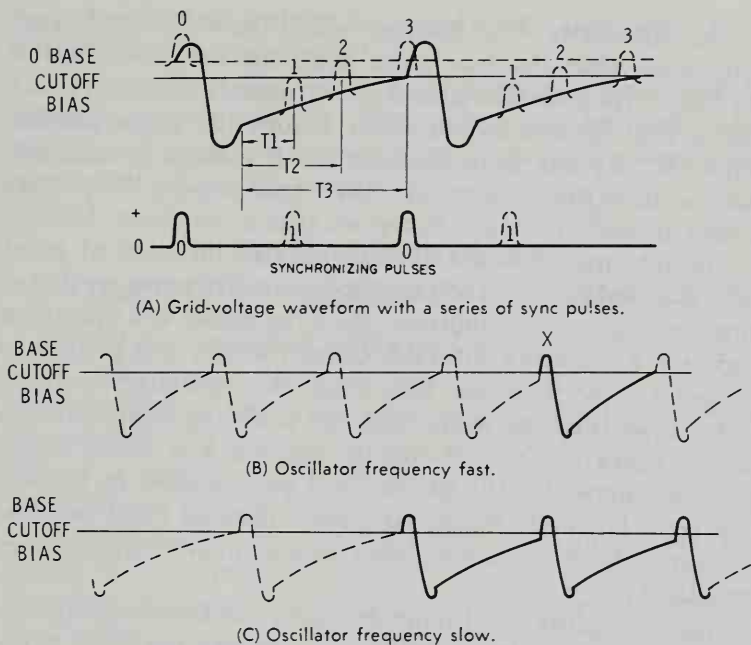
Fig. 16. Pulse control of a free-running oscillator.

step with the wave. These pulses do not affect the free-running frequency of the oscillator. They merely add to the base voltage at the same instant it is being driven positive by the collector-current pulse. On the other hand, if the sync pulses occur at the points indicated as "1", the pulse voltage added to the discharge voltage is still short of the cutoff bias point and will not fire the device. However, if the pulse occurs at points 2 or 3, the critical bias will be exceeded, the device will immediately conduct, and retrace will begin.

Since the free-running frequency of the blocking oscillator can be changed by varying the time constant of the capacitance and resistance in the base circuit, let's examine this action under the following conditions: (1) oscillator running faster than the sync-pulse rate, and (2) oscillator running slower than the sync-pulse rate.

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Fig. 16B shows what happens when the oscillator is running faster than the sync-pulse rate. The dotted portion of the waveform indicates lack of synchronization at that point. Notice that several cycles occur before the pulse reaches point "X". At this point the base cutoff voltage is exceeded, and the tube fires. Normally, you would expect the picture to lock in satisfactorily. However, this is not true. Lock-in occurs only momentarily during the field initiated at point "X". Succeeding fields do not lock in. With the oscillator running in this fast condition, the sync pulses are occurring during the scanning interval. Consequently, the picture is divided by the blanking bar. Also, the oscillator, running faster than the sync-pulse rate, can easily be triggered into erratic operation by automobile ignition and static interference. Therefore, the picture will be unstable. In modern receivers, however, improved circuit designs have resulted in more stable pictures, even under heavy interference conditions.

Fig. 16C shows what happens when the free-running frequency of the blocking oscillator is slower than the sync-pulse rate. Notice that lock-in occurs much faster and a good stable picture is obtained. This is obviously the desired condition because the oscillator should run slightly slower than the sync-pulse rate. The sync pulses will then take over and force the blocking oscillator to lock in with each succeeding sync pulse.

The height and width of the sync pulses are not important as long as they are high enough to drive the base above the cutoff point. With the sync-pulse amplitude reasonably
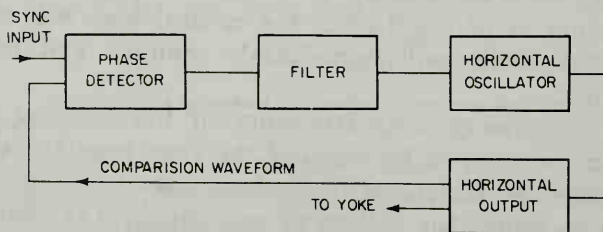
Fig. 17. Block diagram of a horizontal-AFC and deflection system.

high, the hold control can be varied over a fairly wide range without loss of synchronization.

For control of the blocking oscillator just described, the sync pulses are positive. Sync pulses can be made either positive or negative with respect to ground (or chassis), depending on receiver design.

PULSE CONTROL OF
TRANSISTOR HORIZONTAL OSCILLATOR

The basic function of pulse control in a transistor oscillator configuration is to provide horizontal sync lock in a manner that rejects disturbing noise interference insofar as possible. This control of the horizontal oscillator frequency is similar to that found in tube-type TV receivers. To minimize picture tearing or other disturbances due to random noise pulses, the horizontal-sync pulses are processed in a comparator circuit which has a comparatively long time constant. The frequency of the horizontal oscillator, in turn, is controlled indirectly, and the noise-pulse voltages tend to average out and cancel.

Horizontal sync pulses are mixed in a diode circuit along with comparison waveforms from the horizontal sweep section. In turn, a DC control voltage is developed which opposes any tendency of the horizontal oscillator to drift off-frequency. The control voltage is applied through an RC network which has an appreciable time delay, so that successive noise pulses tend to cancel one another. Fig. 17 shows the plan of the pulse-control network. A basic automatic frequency control (AFC) circuit is shown in Fig. 18. Sync pulses and the comparison sawtooth waves are fed into the diode circuit. In turn, the sync pulses ride on the sawtooth waves. Note that the peak-to-peak voltage of the combination waveform is thereby increased.

Capacitor C in Fig. 18 can be charged only if one of the diodes conducts more than the other. If the oscillator happens to be exactly on-frequency, both diodes conduct equally because voltages V1 and V2 are equal. On the

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other hand, if the oscillator tends to run too slowly, the wave-forms are changed and D2 conducts more than D1. Hence, the upper terminal of C becomes negative, and a negative control voltage is produced. If the oscillator tends to run too slowly, a positive control voltage is produced. This control voltage is fed directly to the oscillator, or to a control device; in either case, the control voltage corrects the oscillator frequency.
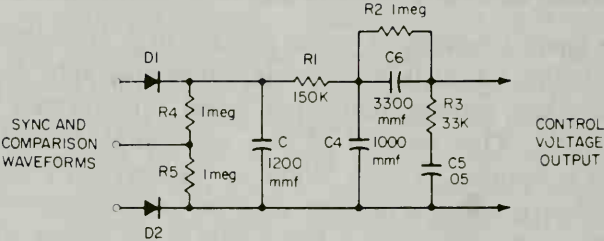
(A) Basic AFC circuit.
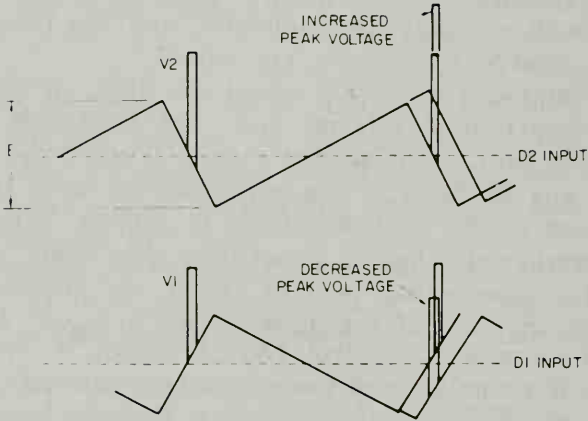
(B) Operating waveform.

Fig. 18. Peak voltages change when the phase of the comparison waveform changes.

The RC network to the right of C in Fig 18 is basically an integrating and filter circuit which delays and smooths the control voltage. This configuration also provides a fast

initial correction, followed by a slower correction in the same direction which eases the oscillator to its correct frequency without over-correction. When a defect occurs in this network, the result is often an over-correction alternating with an under-correction. The result is a picture symptom called the "pie-crust effect." Technicians term the circuit action as "hunting" when the picture has a pie-crust or gear-tooth appearance. (See Fig. 19).
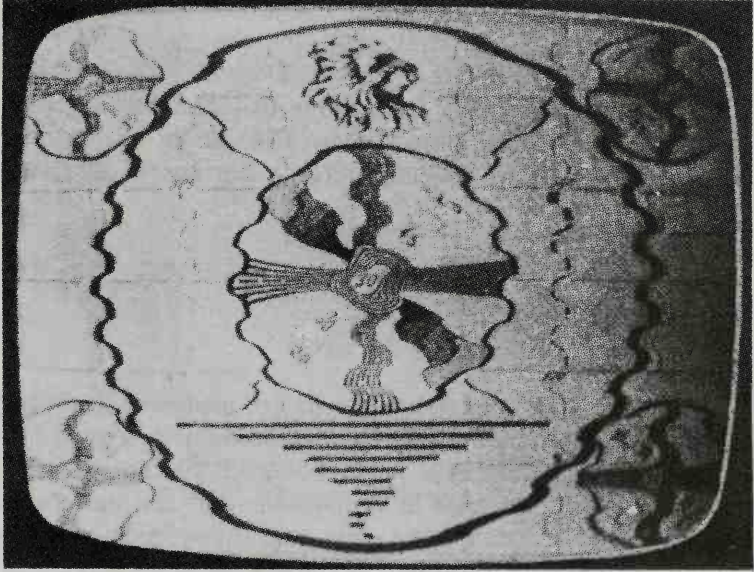
Fig. 19. Typical pie-crust trouble symptom.

Summary of Scanning-Generator Pulse Control

1. A positive synchronizing pulse controls the frequency of a blocking oscillator.
2. A negative pulse controls the frequency of a cathode-coupled multivibrator.
3. The free-running frequency of the scanning oscillator should always be slightly less than the synchronizing-

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3. The free-running frequency of the scanning oscillator should always be slightly less than the synchronizing-pulse repetition rate. The hold, or frequency, control of the oscillator controls this action.

4. As the base voltage of a pulse generator approaches the "trigger" point, the oscillator becomes increasingly sensitive to control by additional base voltage. At this point, the scanning can be "tripped" by interference. Special circuit combinations have been devised which are controlled by the pattern of the pulses, rather than by the individual pulses. Such a system is relatively insensitive to interference, which seldom has a regular pattern. Fig. 20 shows the basic troubleshooting procedure for a horizontal AFC and oscillator section.

SCANNING

The amount an electron beam in an electromagnetically deflected cathode-ray tube is deflected depends upon the strength of the magnetic field produced by the deflecting coils. The magnetic field is proportional to the amount of current passing through the coils, and these fields cross the path of the electron beam within the neck of the tube.

We must supply a linear sawtooth of current through the coil so that the electron beam will trace the proper raster under the combined influence of the horizontal- and vertical-deflecting coils. In Fig. 21 we see the resultant shape of a current wave which would flow through a pure inductance if a symmetrical square wave of voltage were applied across its terminals. This type of wave, as we have seen, can be developed by a conventional or symmetrical multivibrator. At point A, the voltage has suddenly been applied to the coil in much the same fashion as if a switch had been closed to connect the coil to a DC source of potential, for example, a battery.
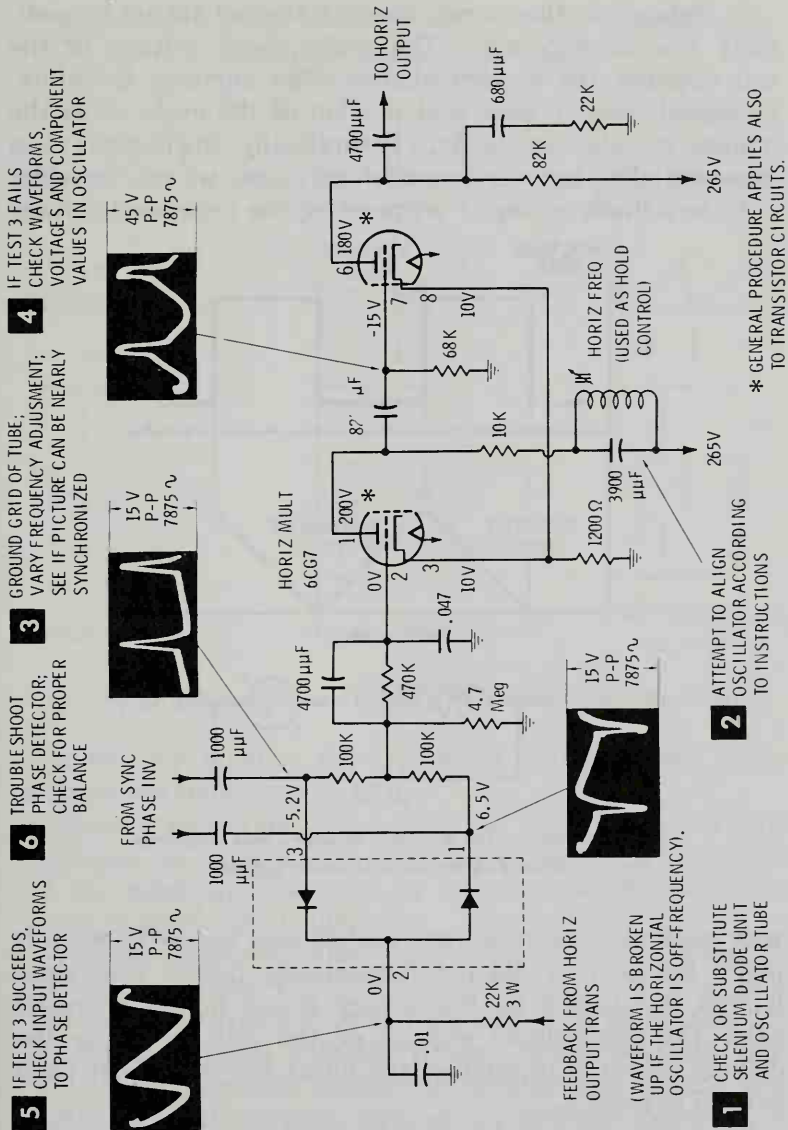
Fig. 20. Basic troubleshooting procedure for a horizontal AFC-oscillator section using two semiconductor diodes.

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Notice that the current through the coil did not immediately rise to maximum. The self-induced voltage of the coil opposed the sudden change. The current, therefore, increased linearly over that portion of the cycle when the applied voltage was steady. (Theoretically, the current rises exponentially; but for practical purposes, we can consider it to be a linear change.) At point B, the impressed voltage
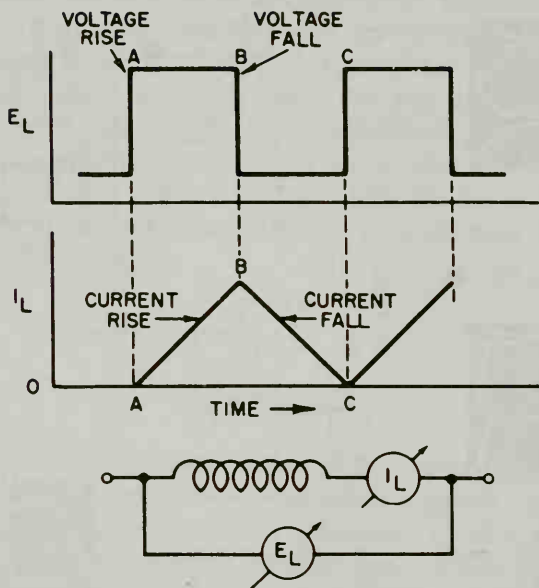
Fig. 21. Rise and fall of current through a pure inductance when a square voltage wave is applied.

was suddenly removed (the switch was opened). At this point, the current did not immediately fall to zero since it was maintained by the energy stored in the magnetic field. The self-induced voltage of the coil served as the driving potential to produce the linear fall of current from point B to point C.

We have now produced a triangular wave of current through the coil. If we can make the rise portion of the curve longer than the decay portion, we can produce the desired sawtooth-scanning current wave. This wave can be

(A) Pure resistance.   (B) Pure inductance.

(C) Series inductance and resistance.
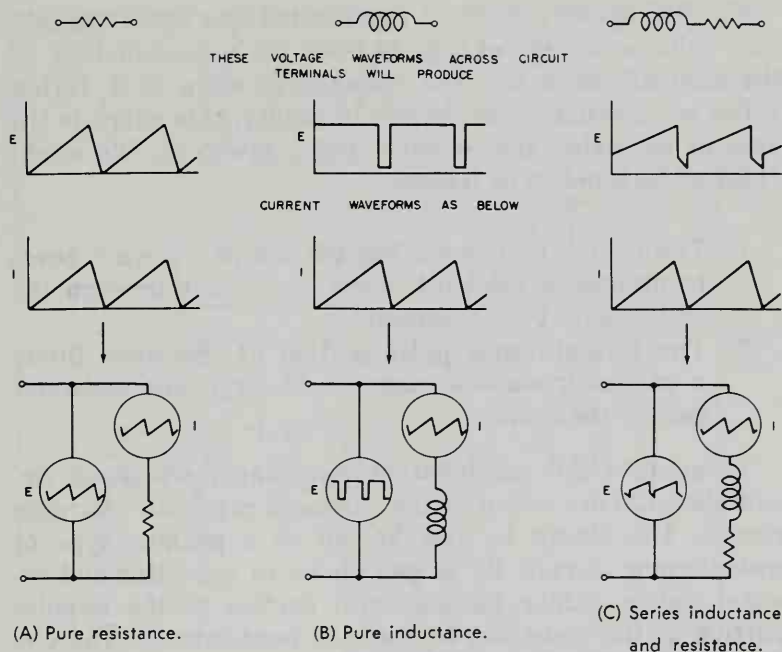
Fig. 22. Voltage and current waveform in inductive and resistive circuits.

produced by making the impressed voltage wave asymmetrical, as shown in Fig. 22B.

Since a deflection coil cannot be built as a pure inductance, we must now consider what effect the resistance of the windings will have on the voltage waveform producing a sawtooth of current.

Fig. 22 illustrates three types of circuits and the voltage waveform necessary to produce a sawtooth wave of current through each circuit. Fig. 22A shows a pure resistance. The current is in phase with the voltage, and a sawtooth wave of voltage impressed across the resistor will cause a sawtooth wave of current through it. Energy losses occur only in the form of heat. The voltage required to produce a certain current is equal to the IR drop, as determined by Ohm's law.

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Fig. 22C shows the circuit represented by a deflection coil. The voltage waveform will be seen as a combination of the sawtooth of A and the rectangular wave of B (often called a trapezoidal waveform). In reality, this shape is the sum of an instantaneous pulse and a sawtooth. We might think of its function as follows:

1. The sawtooth or linear rise portion of the wave tends to produce a sawtooth wave of current through the resistive part of the circuit.
2. The instantaneous pulse portion of the wave forces a sawtooth wave of current through the inductive part of the circuit.

To produce this combination waveshape, additional circuit elements are added to the sawtooth-capacitor charging circuit. The circuit is then known as a peaking type of waveshaping circuit. By proper choice of capacitor and resistor values, either the sawtooth portion or the impulse portion of the wave can be made to predominate. The circuit action will be described later.

It is interesting to note that one part of the wave must predominate over the other because of the differences between the horizontal- and vertical-deflection coils. In the vertical-deflecting coil, the resistive component predominates over the inductive component. Thus, the sawtooth portion of the wave predominates over the impulse portion. For example, this coil might have a resistance of 68 ohms and an inductance of 50 millihenries. When the retrace rate is 60 Hertz, a predominantly resistive circuit is presented.

In the horizontal-deflecting coil of the same receiver, the conditions are reversed; the inductive component predominates. The impulse portion is more important, and the required waveshape approaches that of Fig. 22B. For example, we would find a resistance of only 14 ohms and an inductance of 8 millihenries. Since this coil operates at the much higher frequency of 15,750 Hertz per second, the circuit is essentially inductive.
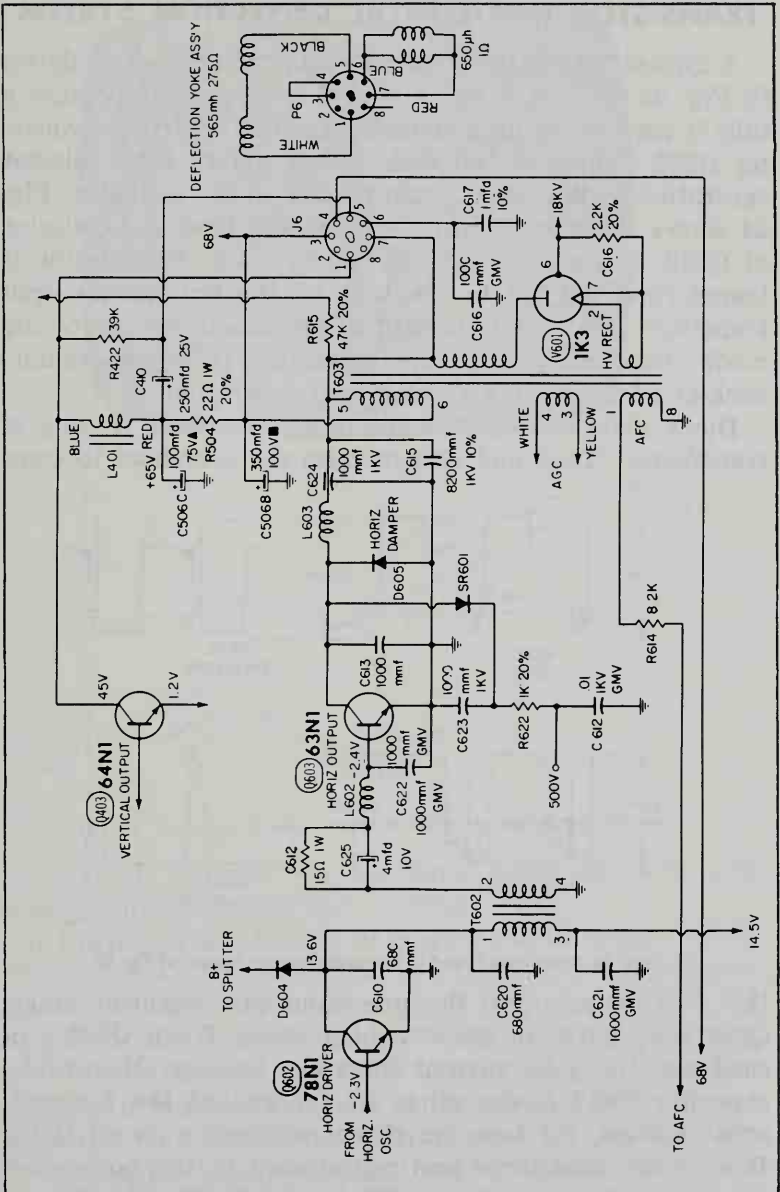
Fig. 23. A typical transistor horizontal-output and high-output voltage configuration.

TRANSISTOR HORIZONTAL DEFLECTION SYSTEM

A typical transistor horizontal-deflection circuit is shown in Fig. 23. This is called a hybrid arrangement because a tube is used in the high-voltage section. The driver transistor Q602 is first cut off and is then driven into collector saturation by the output from the horizontal oscillator. Fig. 24 shows the normal waveforms at the base and collector of Q602. The rectangular waveform from the collector is transformer-coupled to the base of the horizontal-output transistor Q603. Q602 is said to operate in the switching mode; this means that the transistor is driven rapidly back-and-forth between cutoff and saturation.

Diode D604 in Fig. 23 helps to damp out the ringing of transformer T602 and also rectifies the overshoot to boost
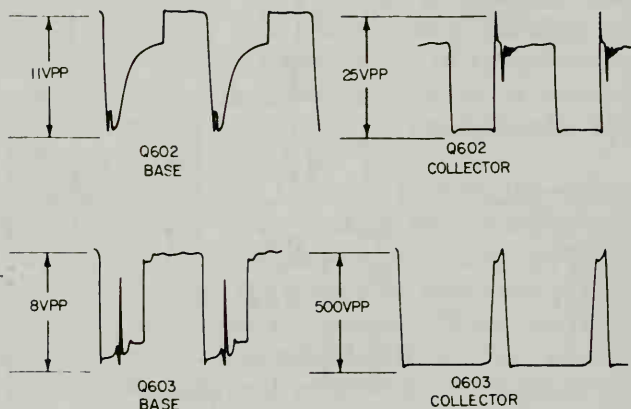
Fig. 24. Waveform found in horizontal-output system of Fig. 23.

the +DC supply for the preceding phase-splitter stage. Q603 is operated in the switching mode. When Q603 conconducts, the yoke current increases linearly. Meanwhile, capacitor C617 is charging. At the end of the forward-scan interval, the base waveform suddenly cuts off Q603. Due to the inductance and capacitance of the horizontal-output system, a ringing oscillation starts: Ringing begins with a large positive overshoot pulse that quickly reverses
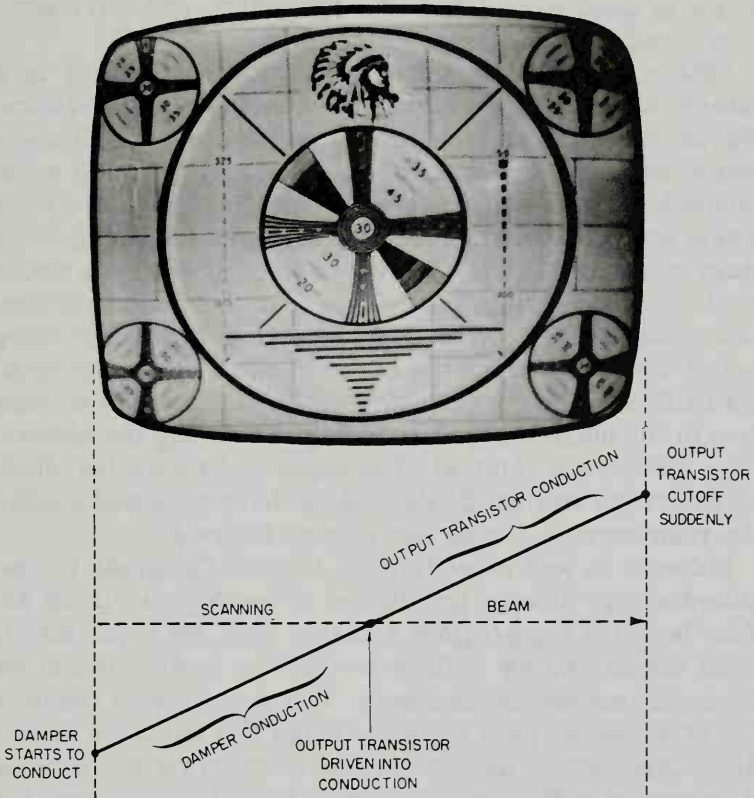
Fig. 25. Sequence of circuit action in the horizontal-output system.

the current through the horizontal-deflection coils and
thereby initiates the flyback interval.

As the negative half-cycle of ringing starts, damper diode
D605 becomes forward-biased. In turn, the low impedance
imposed by D605 limits the negative ringing excursion. At
the same time, C617 discharges linearly through the hori-
zontal-deflection coils and D605 to ground. This linear dis-
charge provides the first half of the ensuing forward-scan
interval. Fig. 25 illustrates this sequence of circuit action.
To summarize briefly, the first half of the forward scan
occurs while Q603 is cut off, and while C617 discharges
through the yoke and D605. The second half of the scan

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occurs as Q603 is switched into conduction, and C617 proceeds to charge once more through the yoke.

Silicon controlled rectifiers (SCR's) are also used to a considerable extent in horizontal-deflection configurations. Fig. 26 shows the arrangement of a typical system. It operates from an unregulated DC power supply of $+155$ volts. Current and voltage waveforms required by the circuit action are obtained from LC resonant circuits. A regulator stage is included in the circuitry to stabilize scanning under conditions of varying line voltage and changes in picture-tube beam current. With reference to Fig. 27, the trace switch diode D_T and the trace switch silicon controlled rectifier SCR_T provide the switching action that controls current flow in the horizontal yoke windings L_y during the picture-tube beam-trace interval. The commutating switch diode D_C controlled rectifier SCR_C initiate the retrace and control the yoke current during the retrace interval.

Inductor L_R and capacitors C_R, C_A, and C_Y supply the required energy storage and timing cycles for the circuit action. Inductor L_{CC} provides a charge path for capacitor C_R from the DC supply voltage so that the system recharges from the receiver power supply. The secondary of inductor L_{CC} provides the gate trigger voltage for the trace switch SCR. Capacitor C_R determines the optimum retrace time by its resonant action with inductor L_R. Fig. 28 shows the voltage and current relations during the first half of the trace deflection current interval, from T_0 to T_2. At time T_0, the magnetic field has been established in the horizontal yoke windings L_y. This field generates a decaying yoke current i_y that decreases to zero when the energy in the yoke winding is depleted at time T_2. This current charges capacitor C_y to a positive voltage V_{Cy} through the trace switch diode D_T.

Note that during the first half of the trace interval, just before T_2, the trace controlled rectifier SCR_T is prepared to conduct by applications of a gate voltage pulse V_{GATE}. However, SRC_T does not conduct until a forward bias is also applied between its anode and cathode. This forward bias is
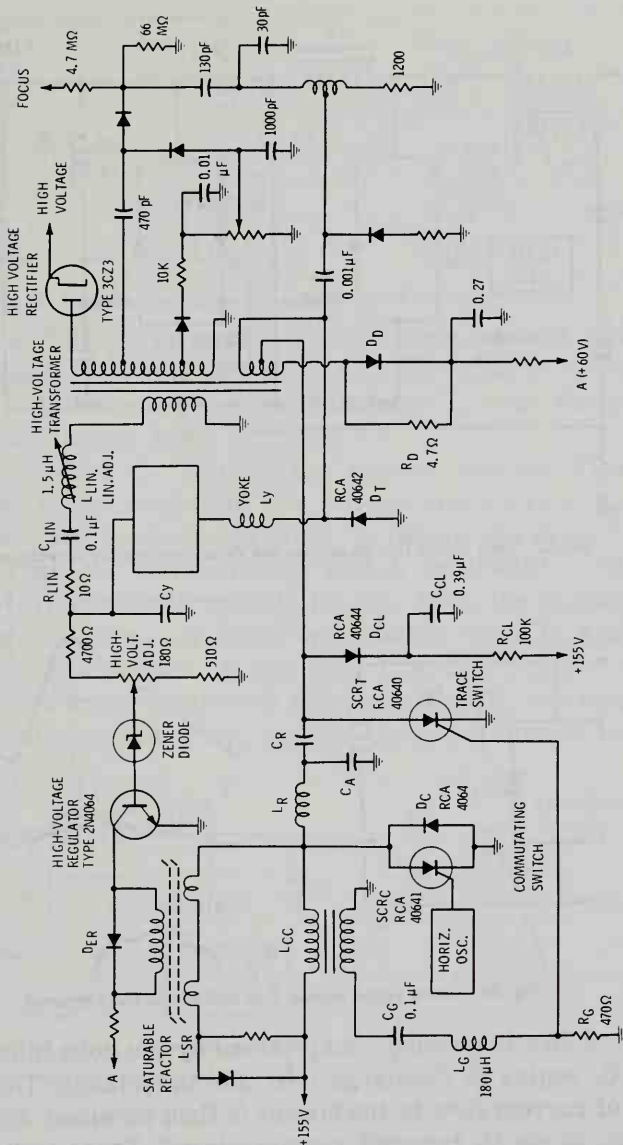
Fig. 26. Configuration of an SCR horizontal-deflection system.

applied during the second half of the trace interval. Next, consider the second half of the trace interval. At time T_2,
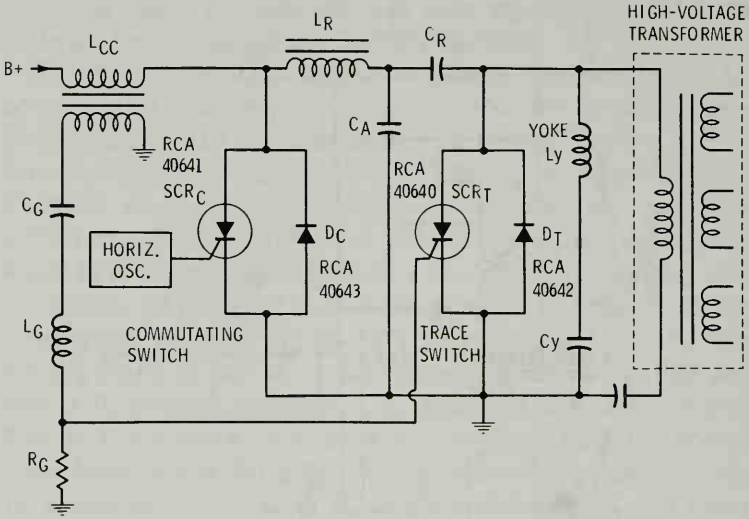
Fig. 27. Basic circuit that generates the deflection current waveform.
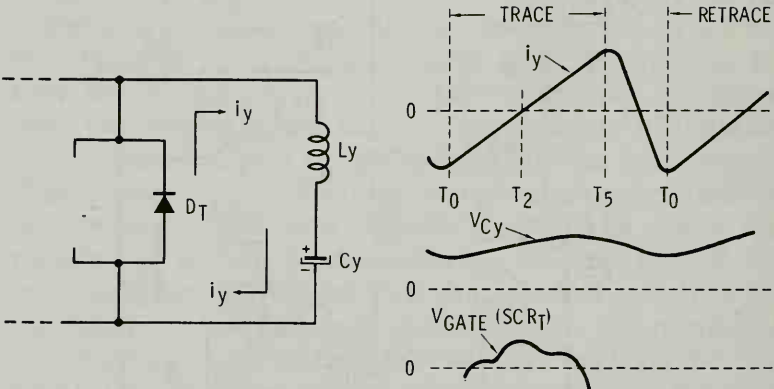
Fig. 28. Circuit action during first half of the trace interval.

current flow is no longer maintained by the yoke inductance, and C_y begins to discharge into this inductance. The direction of current flow in the circuit is then reversed, and trace switch diode D_T becomes reverse-biased. Trace switch controlled rectifier SCR_T is then forward-biased by V_{Cy} across the capacitor, and the capacitor then discharges into the yoke inductance through SCR_T, as shown in Fig. 29. Capaci-
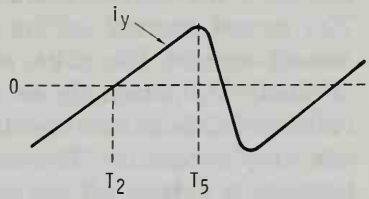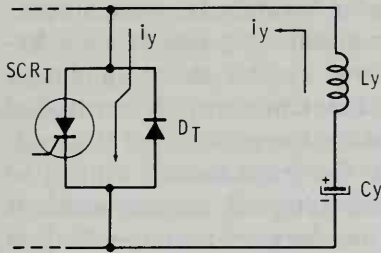
Fig. 29. Circuit action during the second half of the trace interval.

tor C_y is sufficiently large that V_{Cy} is almost constant during the complete trace and retrace cycle. This ensures a linear current rise through the yoke inductance L_y over the complete scan interval from T_0 to T_5.

Next, consider the start of the retrace interval. Fig. 30 shows the components and the voltage and current waveforms that are involved. At time T_3, before the end of the trace period, the commutating switch controlled rectifier SCR_C is turned on by a pulse to its gate from the horizontal oscillator. C_R is then permitted to discharge via SCR_C and inductor L_R. The current in this loop (the commutation circuit), builds up as a half-sine pulse. At time T_4, the magnitude of this current pulse exceeds the yoke current value
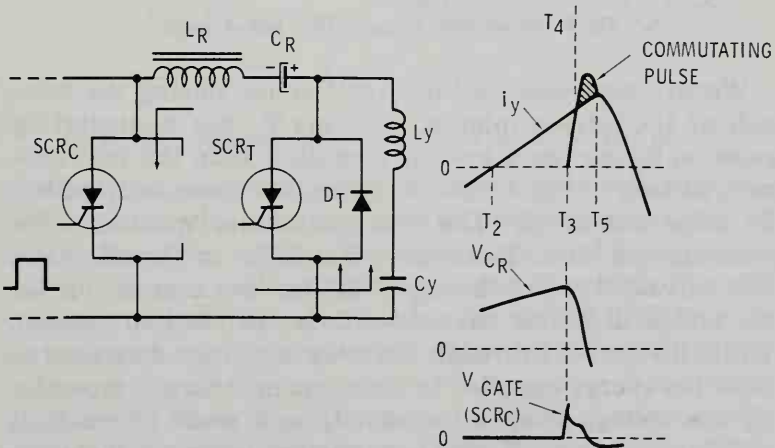
Fig. 30. Circuit action from time T_3 to T_5.

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and the trace switch diode D_T again becomes forward biased. The excess current in the commutating pulse is then bypassed around the yoke winding by the shunting action of diode D_T. From T_4 to T_5, the trace switch controlled rectifier SCR_T is reverse-biased by the amount of the voltage drop across D_T. Therefore, the trace switch controlled rectifier is turned off during this interval, during which it recovers its ability to block the forward voltage that is subsequently applied.
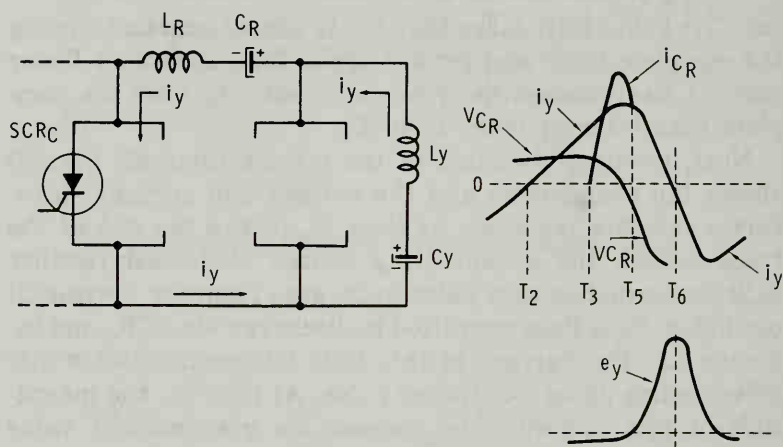
Fig. 31. Circuit action during the first half of retrace.

We will next observe the circuit action during the first-half of the retrace interval. At time T_5, the commutating pulse no longer has a greater amplitude than the yoke current, as seen in Fig. 31. At this time, the trace switch diode D_T stops conduction. The yoke inductance maintains the yoke current flow. However, with SCR_T in its off state, this current flows in the commutating loop comprising L_R, C_R, and SCR_C. Note that time T_5 is the start of retrace. While the current through the yoke windings decreases to zero, the energy supplied by this current charges capacitor C_R to a voltage of opposite polarity as a result of resonant oscillation. At time T_6, the yoke current is zero, and capacitor C_R is charged to its maximum negative value. This

circuit action completes the first half of the retrace interval.

Next, consider the circuit action that occurs during the second half of the retrace interval. At time T_6, the magnetic energy in the yoke inductance is depleted, and the stored charge in the retrace capacitor is then returned to the yoke inductance. This circuit action reverses the direction of current flow through the yoke. During the reversal of yoke current, the commutating switch diode D_C provides the return path for the loop current, as shown in Fig. 32. The commutating switch controlled rectifier SCR_C is reverse-biased by the value of the voltage drop across diode D_C. Therefore, the commutating switch controlled rectifier turns off and its voltage-blocking capability is recovered. As the yoke current builds up in the negative direction, the voltage across the retrace capacitor C_R decreases.
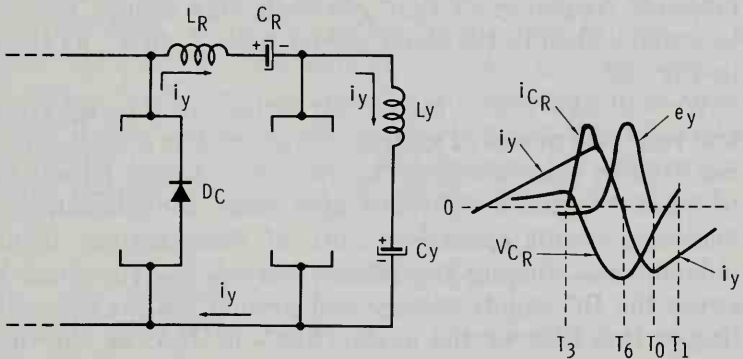
Fig. 32. Circuit action during the second half of retrace from T_6 to T_0.

Note that at time T_0, the voltage across capacitor C_R no longer supplies a driving voltage for the yoke current to flow through the loop comprising L_R, C_R, and L_y. In other words, the yoke current finds an easier flow path through the trace switch diode D_T, as seen in Fig. 33. This circuit action represents the beginning of the trace period for the yoke current, or, the beginning of a new cycle of operation at time T_0. Once that the negative yoke current is decoupled from the commutating loop by the trace switch diode, the current flow through the commutating circuit

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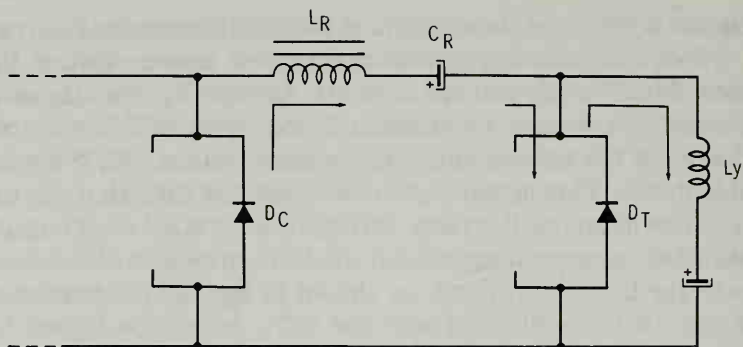
Fig. 33. Operation of the deflection circuit during switchover from retrace to trace at T_0.

decays to zero. In turn, the stored energy in L_R charges C_R to an initial amplitude of positive voltage. Since the resonant frequency of L_R/C_R is high, this energy transfer is accomplished in the short period from T_0 to T_1, as shown in Fig. 32.

We will now follow the circuit actions in the recharging and resetting modes of system operation. The circuit actions required to restore energy to the commutating circuit and to reset the trace SCR are also basic considerations in deflection-circuit operation. Both of these actions involve inductor L_{CC}. During the retrace period, L_{CC} functions between the DC supply voltage and ground via the commutating switch SCR or the diode (SRC_C or D_C), as shown in Fig. 34. When the SCR and diode stop conducting, however, the path from L_{CC} to ground is opened. In turn, the energy stored in L_{CC} during the retrace interval proceeds to charge C_R through the $B+$ supply, as seen in Fig. 35. This charging action continues through the trace period until the start of retrace. The resulting charge on C_R resupplies energy to the yoke during the retrace interval.

Observe that the voltage developed across L_{CC} during the charging period of C_R functions to forward-bias the gate electrode of the trace SCR, thereby readying this device for conduction. This voltage is inductively coupled from L_{CC} and is applied to the gate of SCR_T via the waveshooting
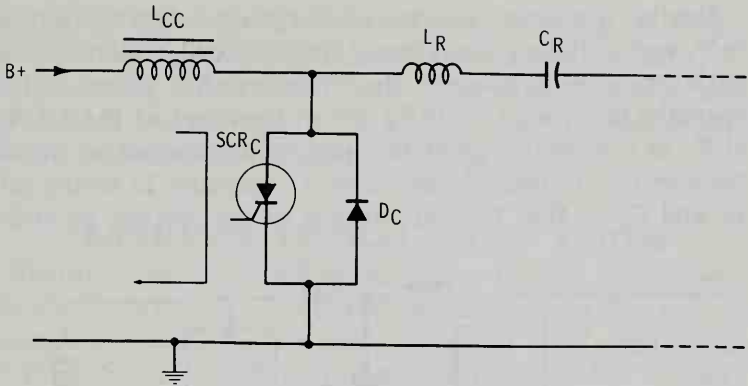
Fig. 34. Energy is supplied to L_cc from T₃ to T₁.

network comprising L_G, C_G, and R_G. This signal voltage is
applied to the gate of SCR_T; the device conducts when a
forward bias voltage is applied from anode to cathode, at
approximately the midpoint of the trace interval. Next, it
is helpful to observe the function of capacitor C_A. It affects
some of the circuit waveforms, as shown in Fig. 36, assists
in turnoff of the trace SCR, and reduced the retrace time
while providing increased energy storage in the circuit.
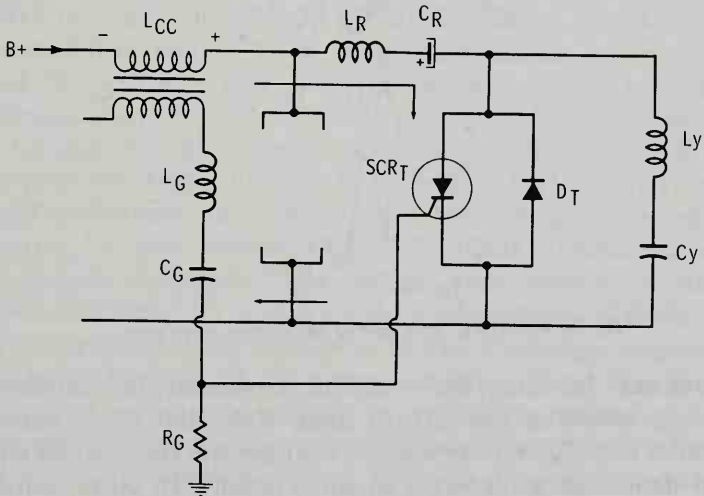
Fig. 35. Circuit action during the period from T₁ to T₃.

During the larger portion of the trace interval, from T_0 to T_4 and including the interval from T_3 to T_4 while the commutating pulse is present, the trace switch is closed and C_A operates in parallel with C_R. From the start of the retrace at T_4 to the beginning of the next trace interval at T_0, the trace switch is open. At this time, C_A operates in series with L_y and C_R so that the capacitance in the retrace circuit is
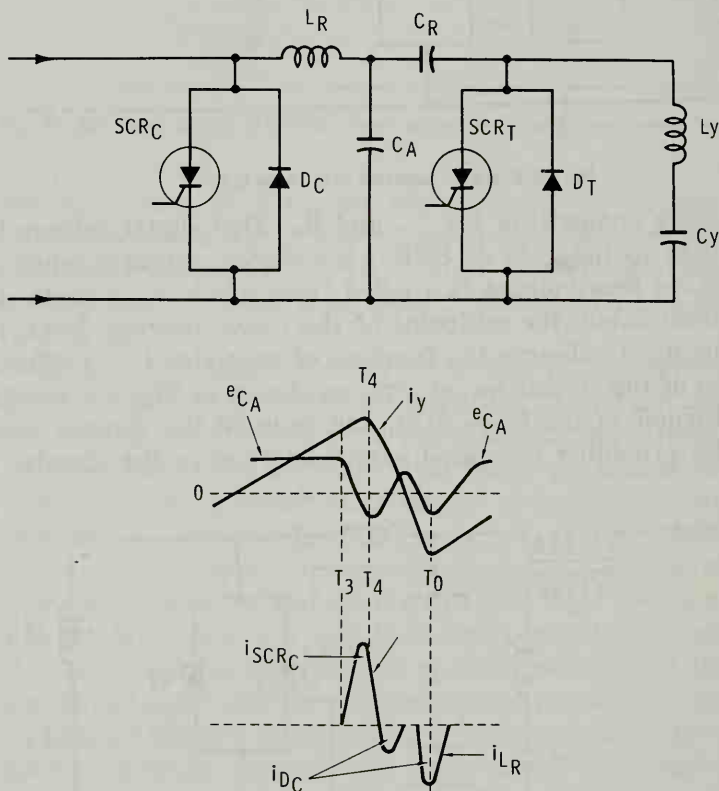
Fig. 36. Effect of C_A with current and voltage waveforms.

decreased. In turn, the resonant frequency is decreased, thereby reducing the retrace time. Note that C_A is also in parallel with L_R. This operation changes the voltage and current deflection waveforms to some extent. In other words, the discharge around the loop occurs at a higher frequency

than would otherwise take place. Troubleshooting of the deflection system is often facilitated by a careful checkout of the operating waveforms. Note if an error is made and SCR_c-D_c is interchanged with SCR_T-D_T, the deflection will operate almost (but not quite) normally.

TRANSISTOR VERTICAL SWEEP SYSTEM

Operation of the blocking oscillator in Fig. 7 has been explained previously. The pulse waveform from Q14 is first changed into a sawtooth waveform by the same circuit that provides the time constant of the blocking oscillator, namely, C21 and R79. Discharge of C21 through R79 produces a curved (exponential) waveform which is then linearized by means of negative feedback via R81. Manual control of vertical linearity is necessary, and this is provided by R6B which operates in combination with C77 to introduce controlled waveshaping. The resulting sawtooth wave can be made either convex or concave by adjustment of R6B. Between these two extremes, the desired linear sawtooth waveform is obtained.

It is also necessary to control the amplitude of base drive to Q15 in Fig. 7 in order to adjust the raster height. This is provided by control R7A. Negative feedback is also provided for Q15 and R89. That is, the waveform from the vertical-deflection coil returns to ground through the emitter resistor for Q15. Some additional negative feedback is also provided from collector to base of Q15 via R83. These negative-feedback circuits not only serve to produce basic linearity in the system, but also make tolerances on replacement transistors less critical than otherwise. Any residual nonlinearity is corrected by adjustment of R6B.

The vertical-output transistor in Fig. 7 employs a power transistor. Because of the comparatively critical bias that is required, a bias control R6C, is provided for maintenance adjustment. Q16 operates near its maximum rated output, and since the collector current is heavy, the collector junction heats up appreciably. Although a heat sink (heavy

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metal mounting) is used, the transistor heats sufficiently in normal operation that the bias voltage must be stabilized. Unless the base-emitter voltage is stabilized, thermal run-away and resulting damage to the transistor would occur. R86 is a thermistor which operates to control the forward bias on Q16, and thereby stabilizes operation. When the emitter-base current tends to increase, R86 heats up and its resistance decreases. In turn, the base voltage is de-creased.

Since the vertical-deflection coils have both resistance and inductance, a peaked-sawtooth waveform is required to produce a sawtooth current through the coils. The negative peaking spike at the collector of Q16 is produced by induc-tive kickback from inductor T3 and the vertical-deflection coils. Note that although there are only 8.6 volts DC be-tween the collector and emitter of Q16, this inductive kick-back generates a total peak-to-peak voltage of 50 volts for the output waveform. The peaking pulse is tapped off for vertical-retrace blanking of the picture tube. Negative feed-back is provided by the unbypassed emitter resistor R90, which also assists in DC stabilization of Q16.

SUMMARY

The multivibrator, blocking oscillator, and sine-wave oscillator are the three types of circuit arrangements gen-erally used to produce sawtooth waveforms for scanning purposes. One of the most popular circuits is the multivibra-tor. The multivibrator is useful because devices can act as automatic switches to control the charge and discharge of capacitors.

The horizontal and vertical pulses are clipped from the signal, amplified, and passed through circuits which classify the pulses so that each will control its own scanning oscil-lator only. The end result is a short, sharp pip for the hori-zontal control and a long, triangularly shaped pulse for the vertical control. The height and width of the sync

pulses are not important as long as they are high enough to drive the grid above the cutoff point.

REVIEW QUESTIONS

1. What three circuits are used for scanning purposes?
2. Which circuit for scanning is most popular?
3. How does an SCR deflection circuit operate?
4. Sync pulses can be either positive or negative. Which pulse is ideal for the cathode-coupled multivibrator?
5. What type oscillator is generally used in transistor television receivers?

Power Supplies

Power supplies in television systems are more complicated than those normally found in radio and other electronic devices. At least two separate and basically different load conditions must be provided for in the set.

1. A low-voltage, high-current system to power the oscillator, amplifier, and similar stages where applied potential does not exceed 450 volts. In addition, some receivers power the modulation and deflection systems from this source.
2. A high-voltage, low-current system to supply the accelerating anode potential for the cathode-ray or picture tube.

LOW-VOLTAGE, HIGH-CURRENT SUPPLIES

The signal reception portion of the receiver, which includes sound and video amplifier or control tubes, presents a power requirement not greatly different in voltage range from that of other electronic devices. Therefore, this portion of the television power supply is similar to the ones found in large radio receivers.

In general, the voltage requirement is no more than 450 volts. The current required, however, is frequently much greater than that necessary for radio operation. In addition a good supply regulation is needed to operate the sawtooth

oscillators for deflecting the electron beam of the cathode-ray tubes. These oscillators tend to produce currents in the power supply. If not properly filtered, these currents would appear as serious modulation hum in the beam control and sound circuits.

Early receivers required heavy-duty power supplies to provide the current (as much as 300 milliamperes in some receivers) drawn by the 30 to 40 tubes in the receiver. These supplies employed from one to three rectifiers; the number, of course, depended upon the current requirements and the designer's preference as to voltage and current distribution.

Practically all power supplies use one of the basic rectifier circuits: the half-wave rectifier, the full-wave rectifier, or the bridge rectifier, as shown in Fig. 1. Half-wave rectifier and bridge-rectifier circuits may be modified to provide pow-
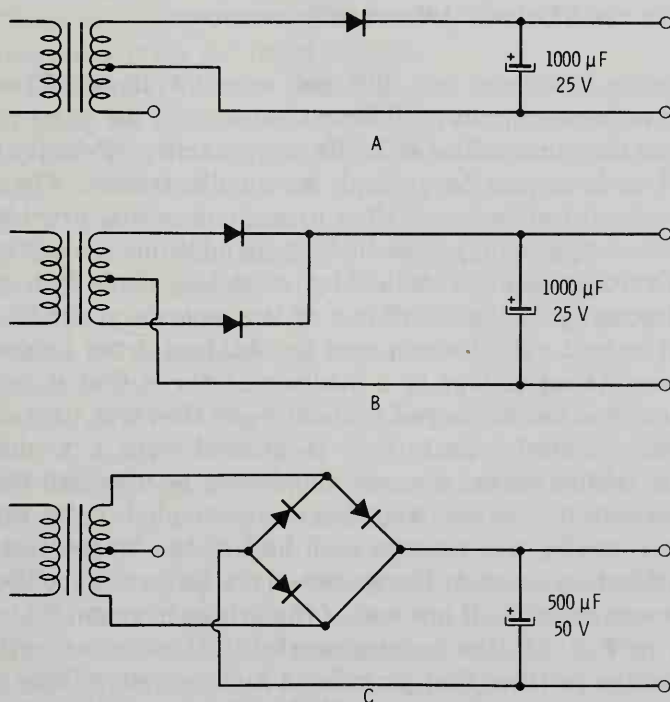
Fig. 1. Three basic rectifier circuits.
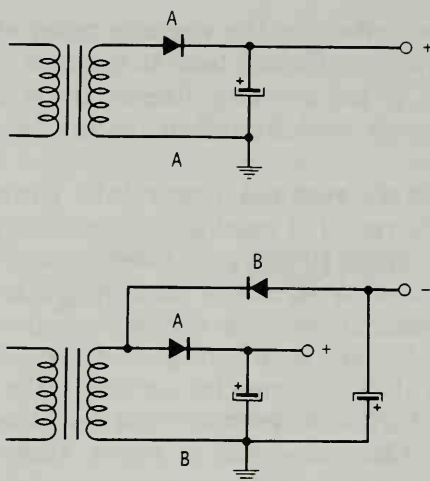
Fig. 2. Dual-output half-wave rectifier arrangements.

er supplies that have two different output voltages. These output voltages may have different values and the same polarity, or the same values and different polarities. Polarity is defined with respect to ground. As an illustration, Fig. 2 shows a basic half-wave rectifier arrangement that provides a positive output voltage via diode A. In addition, a negative output voltage may be obtained by connecting diode B in reversed polarity to the "hot" end of the secondary winding.

Dual output voltages can also be obtained from bridge-rectifiers. An advantage of a bridge rectifier is that it does not require a center-tapped transformer. However, in case the center-tapped transformer is utilized with a bridge-rectifier configuration, a power supply can be provided that has two output voltages. Addition of a grounded center tap, as shown in Fig. 3A, permits each half of the bridge recti-fier to function as an ordinary two-diode full-wave rectifier of a chosen polarity. If one end of the bridge is grounded, as shown in Fig. 3B, the arrangement functions as an ordinary bridge rectifier that provides a high output voltage at the + + terminal, and as a two-diode full-wave rectifier that provides half as much output voltage at the + terminal.
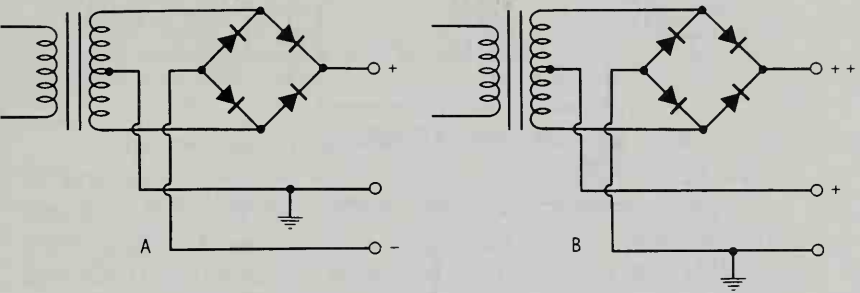
Fig. 3. Dual-output bridge rectifier configurations.

The next step in complexity concerns voltage multipliers. These are configurations that supply DC voltages which are multiples of the AC input voltage.

Full-Wave Voltage Doubler—The circuit shown in Fig. 4C can be modified by removing the ground connection between the two capacitors, and a standard full-wave voltage-doubler arrangement is obtained, as shown in Fig. 4A. Note that two half-wave rectifier circuits of opposite polarity have been combined, with the output taken from across both capacitors to obtain double output voltage. A voltage multiplier circuit is often used in equipment where a high DC output voltage is required from a transformerless power supply.

Half-Wave Voltage Doubler—A standard half-wave doubler arrangement, shown in Fig. 4B is often preferred to the full-wave arrangement. An advantage of the half-wave doubler is that it does not require a transformer. On the other hand, a half-wave doubler has a ripple frequency equal to the line frequency, whereas a full-wave doubler has a ripple frequency equal to twice the line frequency. In turn, larger filter capacitors are required in the half-wave doubler arrangement.

Half-Wave Voltage Tripler—A half-wave voltage tripler operates on the same basic principle as a half-wave voltage

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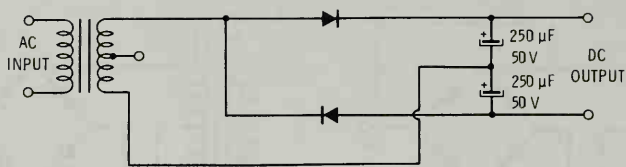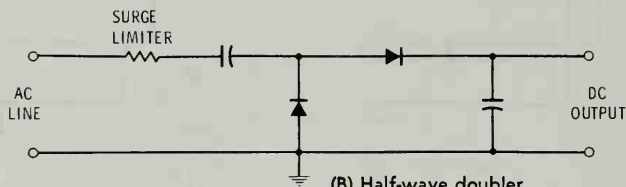
(A) Full-wave doubler.

(B) Half-wave doubler.
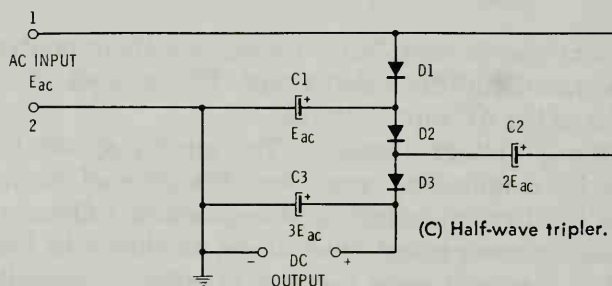
(C) Half-wave tripler.
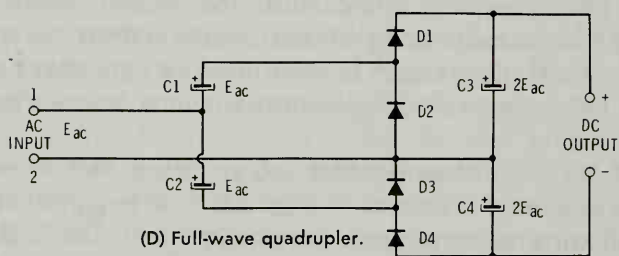
(D) Full-wave quadrupler.

Fig. 4. Voltage multiplier configurations.

doubler. Fig. 4C shows the tripler configuration. Since it uses a ground connection to one input line, a transformer is not required.

Full-Wave Voltage Quadrupler and Sextupler—When two half-wave voltage doublers are connected so that their outputs are effectively in series, a full-wave voltage quadrupler
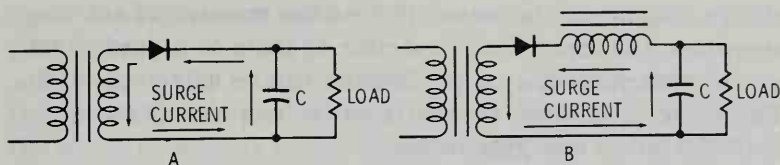
Fig. 5. Examples of surge-current paths for two basic filter circuits.

arrangement results, as shown in Fig. 4D. In the same manner, a full-wave voltage sextupler results from connecting two half-wave voltage triplers so that their outputs are effectively in series. Note that the comparatively complex quadrupler and sextupler arrangements are practical because their semiconductor rectifiers require no heater windings and heater circuits. In other words, their production cost is not excessive.

As a practical note, the foregoing voltage-multiplier circuits use capacitor input filters, and their voltage regulation (Reduction of output voltage with increased current demand) in comparatively poor. Under heavy current demand, the output voltage may decrease as much as 30%. This decrease can be minimized by the use of very large filter capacitors.

FILTER ARRANGEMENTS

Since a semiconductor rectifier has a very low voltage drop in its forward-conduction state, surge currents drawn by filter capacitors must be limited to avoid rectifier damage. With reference to Fig. 5A the starting surge is limited to some extent by the series impedance of the transformer winding. However, if the series resistance of the transformer winding is low, and capacitor C has a large value, a starting current surge can result that damages the rectifier. Capacitor input filters are especially vulnerable to starting current surges. Therefore, it is poor practice to replace an input filter capacitor with a higher value than specified in the receiver service data. In other words, when the power is turned on, a large current flows through the rectifiers to

charge the input filter capacitor. At the moment of starting operation, the input filter capacitor appears as a dead short, and the momentary current demand can be extremely high. Therefore, it is often necessary to include circuit means to limit the initial charging current.

CHOKE INPUT FILTERS

Power supplies that use choke-input filters do not require surge-limiting means. Note that the filter choke shown in Fig. 5B limits the surge current in the same manner that it limits the peak rectifier current during maximum current demand.

RESISTOR SURGE LIMITER

With reference to Fig. 6, a small-valued resistor is often included in series with the AC input to the rectifier. Its value is chosen to limit the surge current to the maximum amount that the rectifier can handle for a short time. Note that surge-current ratings are generally much greater than the
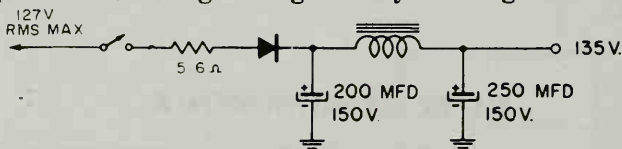
Fig. 6. A typical low-voltage supply using a surge-resistor.

average DC current rating for a rectifier. As an illustration, a silicon rectifier that is rated for an average current of 750 mA has a surge-current rating of 35 amps for 4 milliseconds. Observe also that the series resistance that limits the surge current is chosen with the worst case in mind. Thus, the worst case occurs when power is applied at the instant that the AC voltage is swinging through its positive peak, and the input filter capacitor has zero charge. In the example of Fig. 6, the maximum input voltage is 127 volts rms. Its peak voltage is 180 volts, accordingly. In turn, to limit the surge current to 35 amps, the surge-limiting re-

sistor should have a value of 5.2 ohms, in accordance with Ohm's law.

Following the initial current surge, the filter capacitors become fully charged. Thereafter, the voltage drop across the surge resistor is small. As an illustration, if the current demand in Fig. 6 is 300 mA, the drop across the surge resistor will be 1.56 volts. In practice, transformer power supplies may or may not require a surge resistor with a capacitor-input filter. This depends on the winding resistance of the transformer secondary.

DC VOLTAGE REGULATORS

A basic power supply has significant internal resistance. For example, rectifier diodes have a certain forward resistance, and transformers and chokes have winding resistance. In turn, there is an IR drop across the internal resistance of a power supply that is directly proportional to the current demand. In turn, the output voltage is reduced by the amount of internal voltage drop. Another factor that reduces the output voltage with increased current demand is the fact that the filter capacitors do not charge up to the same voltage as when the discharge rate is small. When the output voltage drops considerably under heavy current demand, the power supply is said to have poor regulation. Note that changes in AC input voltage also cause changes in DC output voltage.
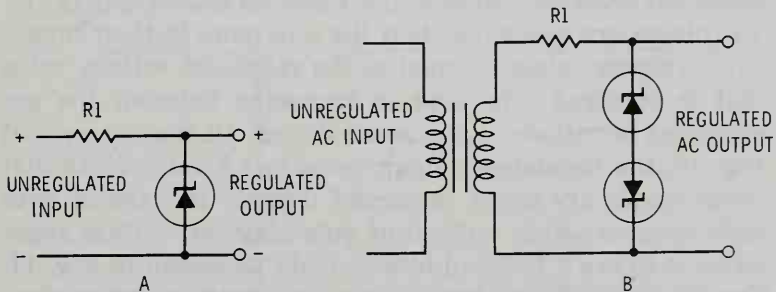
Fig. 7. Basic zener-diode regulator arrangements.

Zener Diode Regulator—Zener diodes are used in configurations such as shown in Fig. 7 to regulate the output voltage. The breakdown voltage of typical zener diodes ranges from 3.9 volts to several hundred volts. Two or more zener diodes may be connected in series to regulate voltages higher than the breakdown value of a single diode, as shown in Fig. 8. Various regulated voltages can be tapped off from a series arrangement of diodes, if needed. The value of the series dropping resistor must be sufficient that the maximum current rating of any diode is not exceeded under worst-case conditions. If the source voltage varies considerably, the cascaded regulator arrangement shown in Fig. 9 is more appropriate.
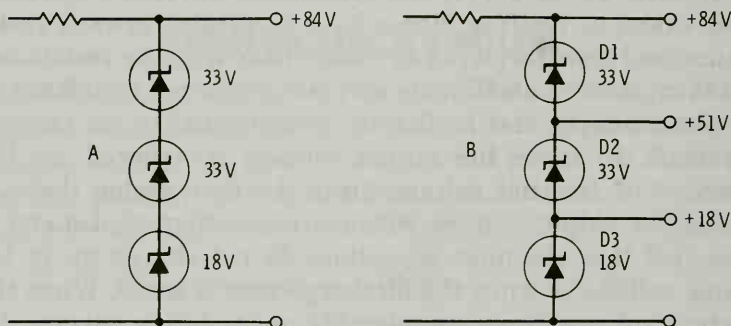
Fig. 8. A stacked zener-diode configuration.

Low-Voltage Zener Regulators—Regulation of very low voltage is done on a differential basis, as shown in Fig. 10. The diodes are selected so that the difference in their breakdown voltage values is equal to the regulated voltage value that is required. The load is connected between the ungrounded terminals of the zener diodes. In the example of Fig. 10, the regulated voltage value is 1.2 volts. Note that zener diodes are never connected directly in parallel with each other. Another method of obtaining low-voltage regulation is to use a forward-biased diode, as shown in Fig. 11. The forward voltage drop across a conducting semiconductor diode is relatively constant over a comparatively great
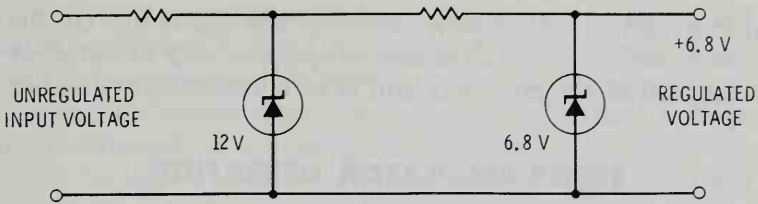
Fig. 9. A cascaded zener-diode regulator arrangement.

current range. A forward-biased diode can regulate voltages in the range from 0.5 to 1.1 volts, depending upon the type of diode that is used. Note that the efficiency of regulation is not as good as provided by zener arrangements.

Transistor Voltage Regulator Arrangements—Low-voltage regulated power supplies often use transistors. This is accomplished by means of some form of feedback circuit that senses any change in the DC output voltage, and in turn develops a control voltage that operates to cancel the change. The control that is operative in the feedback or regulator circuit is a function of the circuit arrangement. This may be a series or a shunt configuration. In a transistor type of regulator, the output voltage developed by the DC power supply is compared with a reference voltage; the difference between these voltages is amplified and fed back to the base of a pass transistor, either linearly, or in the switching mode, and thereby regulates the value of the output voltage. In case the pass transistor can be operated at any point on its characteristic between cutoff and saturation, the regu-
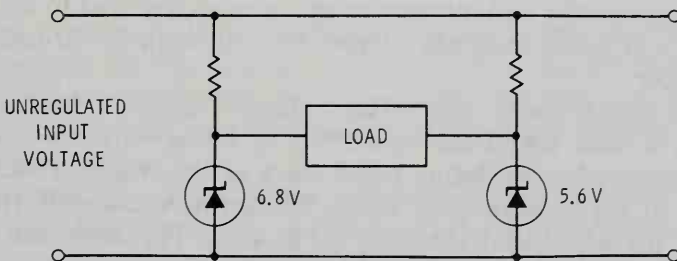
Fig. 10. Zener-diode configuration for regulation of small voltage valves.

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lator circuit is said to be a linear voltage regulator. On the other hand, if the pass transistor operates only at cutoff or at saturation, the circuit is said to be a switching regulator.

SERIES REGULATOR OPERATION

A series regulator configuration uses a pass transistor that is connected in series with the load. In turn, regulating action takes place by a circuit that senses any variation of
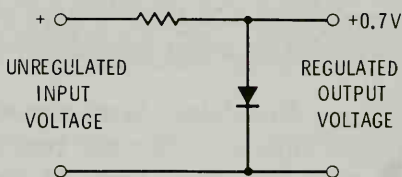
Fig. 11. Basic circuits for very low voltage regulation with a forward-biased diode.

current flow through the series pass transistor due to a change in line voltage or to a change in current demand from the power supply. A corresponding change in voltage drop across the pass transistor in consequence of feedback circuit action will be in opposition to changes in line voltage or to current demand, so that a practically constant voltage drop is maintained across the load. By way of comparison, a shunt regulator uses a pass transistor connected in parallel with the load, and a voltage dropping resistor is connected in series with this parallel circuit branch. In turn, if the load current demand changes, the current flow through the pass transistor will increase or decrease as required to maintain a virtually constant current flow through the dropping resistor.

As noted above, the series voltage regulator functions with a pass transistor connected in series with the load. Consequently, regulation takes place as the result of variation in the voltage drop across the series transistor. Note that the small-load efficiency of a series regulator can be much greater than that of a shunt regulator, inasmuch as no output current is wasted through a branch path shunting

the output. However, the ful-load efficiency of the series and shunt regulators is about the same. A basic series voltage regulator arrangement is shown in Fig. 12. Observe that a DC amplifier is used to step up the error (difference) voltage that is obtained from a comparison between a sample of the output voltage and the reference voltage. This amplified error voltage is then applied to a regulating transistor con-
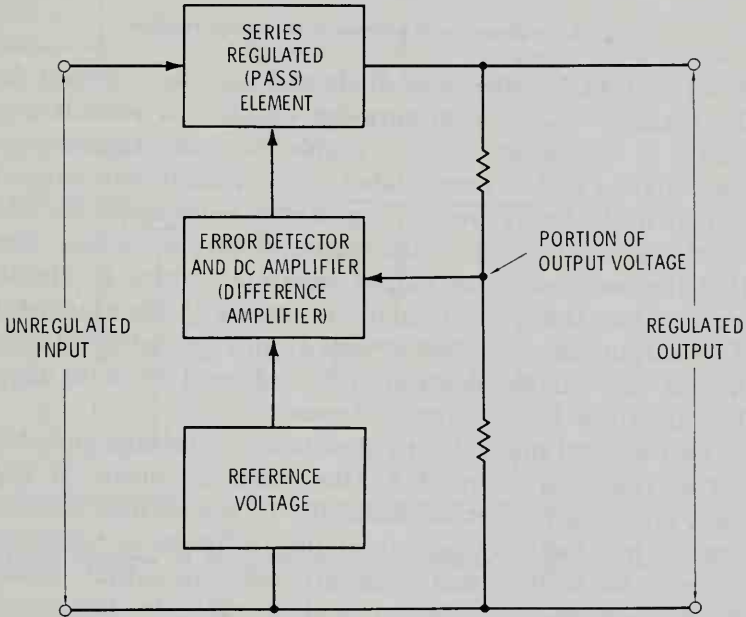
Fig. 12. Arrangement of a basic series voltage regulator.

nected in series with the load. The control voltage is developed across the regulating transistor and is applied to the error detector and amplifier. This error amplifier and the series transistors may include any appropriate number of transistor stages.

Observe the simple series regulator circuit depicted in Fig. 13. The transistor operates in the emitter-follower mode. Input voltage for the transistor is obtained from across the zener diode. Note that the resistor provides break-

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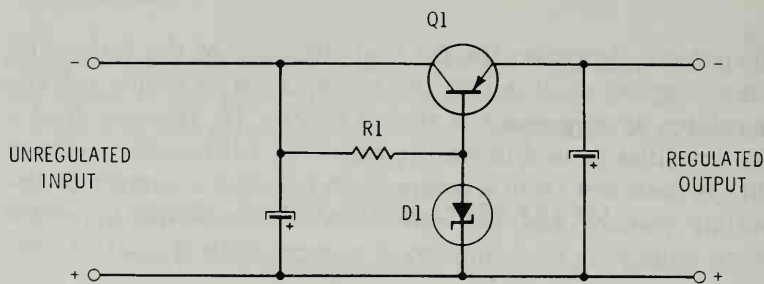
Fig. 13. Configuration of a simple series voltage regulator.

down current for the zener diode and also base current for the transistor. This configuration provides a considerable degree of regulation which is ample for many applications. Any change in the unregulated input voltage will cause a change in the breakdown voltage of the zener diode, thereby causing a small change in the regulated output voltage. Note that the load "sees" an output resistance which is slightly higher than the emitter input resistance of the transistor. This output resistance has a value of approximately 30 ohms with a load-current demand of 30 mA, and drops to about 1 ohm with a 1-amp current demand.

Two general methods are used to apply voltage gain to a series regulator transistor. One method, shown in Fig. 14A, operates the series transistor in the emitter-follower mode. This method places the input to the series transistor between its emitter and collector, with the output voltage taken between the collector and emitter. In the second method, shown in Fig. 14B, the transistor function as a common-emitter amplifier. This method applies the control voltage between the base and emitter, with the output voltage taken between the collector and emitter. Both of the methods described above have approximately the same performance. Note that the differential amplifiers shown in Fig. 14A and B function as difference or error amplifiers. They are basically high-gain direct-coupled arrangements that provide low noise, low drift, and high stability when operated in a feedback loop. Because a differential amplifier configuration is often used as a difference ampli-

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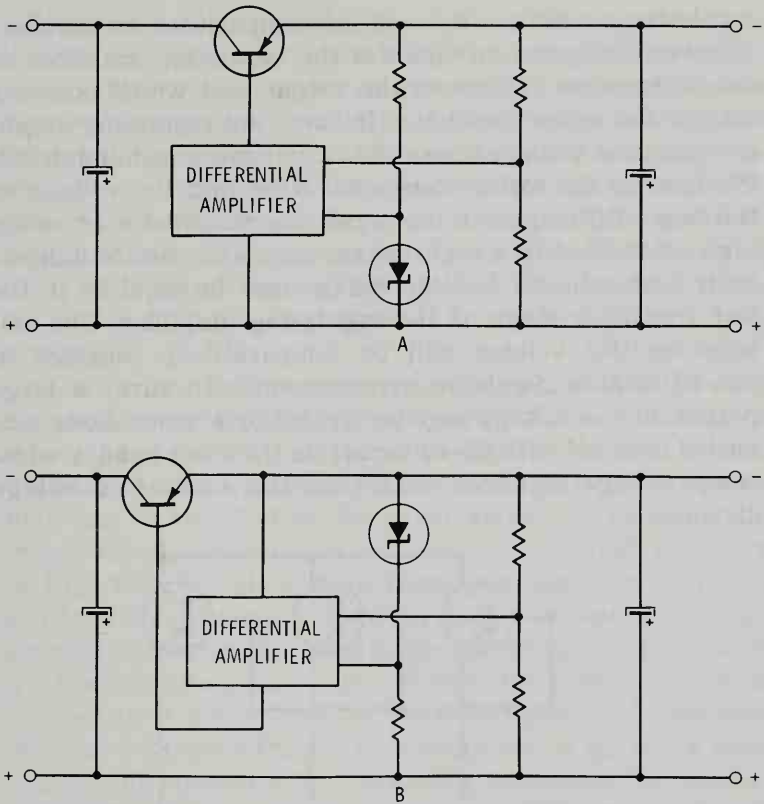
Fig. 14. Examples of series regulating arrangements using error feedback and amplification.

fier, the arrangement is commonly called a differential amplifier.

If a wide output voltage range is required, the emitter-follower arrangement has an advantage, because the voltage applied between the base and emitter is always low, regardless of the output voltage from the regulator. In most cases, it is convenient to have the output from the entire regulating amplifier approximately equal to the emitter voltage of the series transistor. Only a voltage sensing lead is connected to the other output terminal. Accordingly, there is no limitation placed on the regulator output voltage by the

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regulating amplifier. By way of comparison, an emitter-follower configuration operates the regulating amplifier at about the same voltage as the output lead which does not include the series transistor. In turn, the regulating amplier senses the voltage across the output terminals and drives the base of the series transistor. Note that the voltage of the base with respect to the regulating amplifier may be too high when used in a high-voltage regulator, and a dangerously high collector-emitter voltage may be required in the last transistor stage of the regulating amplifier. The collector-emitter voltage will be comparatively constant in non-adjustable regulator arrangements. In turn, a large portion of the voltage may be divided by a zener diode connected in series with the collector. On the other hand, a wide-range voltage regulator cannot use this method of voltage division.
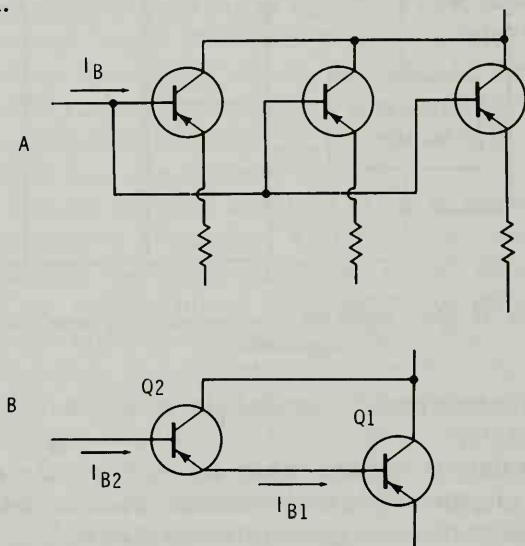
Fig. 15. High-power regulating arrangements.

It is instructive to note that both arrangements shown in Fig. 14 are similar in various other respects also. Thus, the voltage divider senses the output voltage from the power supply and develops an input voltage that is applied to the

differential regulating amplifier. In turn, the output voltage
changes by feedback action to equal the voltage on the zener-
diode reference source. As in ordinary power supplies, the
electrolytic capacitors assist in ripple filtering and protect
the regulator devices against high transient voltages. Ob-
serve that a regulated power supply has very considerable
inherent filtering action, and that the ripple voltage is nor-
mally very small. However, some capacitive filter action is
required between the rectifier(s) and the regulator. Also,
the effective internal impedance of a regulated power supply
is very low.

A series regulating device may consist of a single very
high power transistor, or several power transistors may be
connected in parallel, as shown in Fig. 15. In such a case,
the base current (control current) demand may be greater
than can be supplied by the error amplifier. To meet this
requirement, a Darlington pair may be employed, as shown
in Fig. 15B. In this circuit, transistor Q2 operates in the
emitter-follower mode and drives the series regulating tran-
sistor Q1. Observe that, due to the current gain provided by
Q2, the control current required from the error amplifier if
reduced by a factor equal to the beta value of the emitter-
follower transistor Q2. As an illustration, if Q2 has a betal
value of 50, and the series regulating transistor Q1 requires
a 10-mA control current, the error amplifier must provide
only 0.2 mA of control current. A series regulator arrange-
ment does not have inherent overload protection, and it can
be destroyed by a momentary short-circuit across the output
terminals unless suitable protective measures are provided.
For example, an overcurrent sensing circuit may be in-
cluded, which automatically limits the value of output cur-
rent. Of course, voltage regulation is absent past the current
limiting point.

SHUNT REGULATOR ARRANGEMENTS

Although shunt regulators often have comparatively sim-
ple circuitry, they are usually least efficient for voltage regu-

lation. An advantage of a shunt regulator configuration includes a shunt device and a reference-voltage element, as exemplified in Fig. 16A. Observe that the output voltage remains constant because the shunt-element current changes as the load current varies or as the input voltage changes. Any current change is reflected as a voltage change across R1, which is connected in series with the load. Note that the shunt transistor connected in parallel with the load operates in the common-emitter configuration. For high-power applications several transistors may be connected in parallel, or in a Darlington configuration. A Darlington pair is utilized in the example of Fig. 16B. An arrangement such as shown in Fig. 17 provides very close regulation of the output voltage.
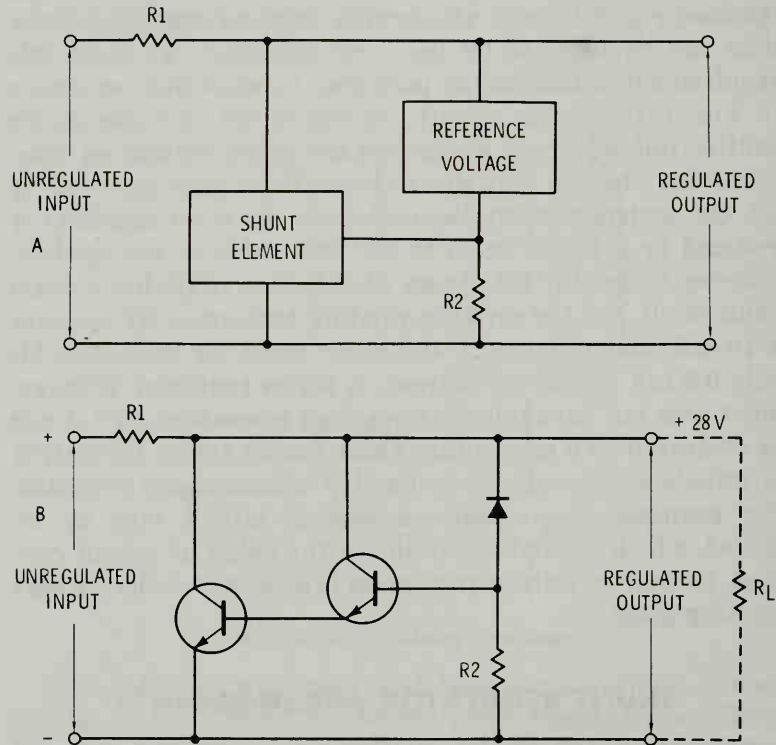
Fig. 16. Basic shunt regulator arrangement.
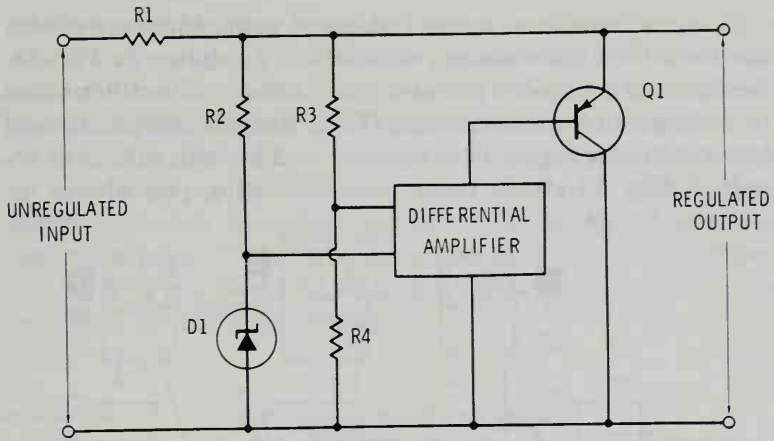
Fig. 17. A configuration that provides close regulation of the output voltage.
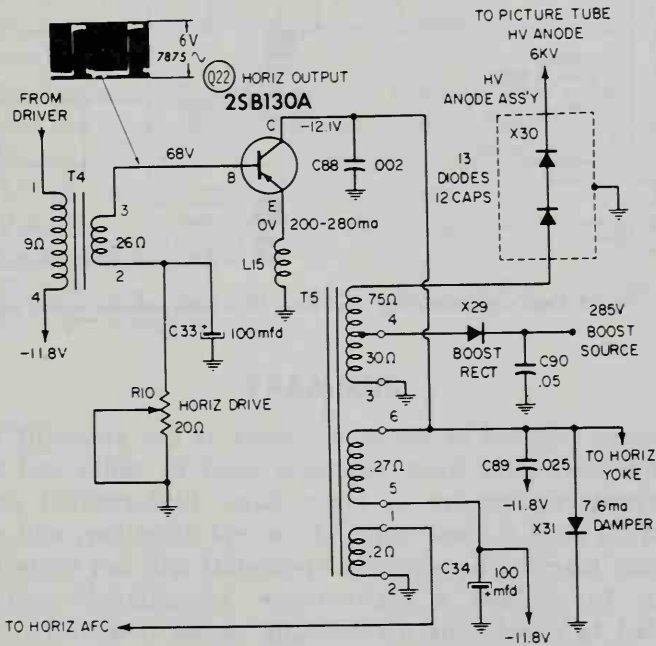
Fig. 18. A stack of 13 semiconductor diodes is used in this high-voltage rectifier assembly.

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In some receivers, series-connected semiconductor diodes are used for high-voltage rectification, as shown in Fig. 18. Semiconductor diodes are also used instead of rectifier tubes in voltage multiplier circuits. They provide simplicity and lower manufacturing cost because no filament supply is required. Fig. 19 shows basic troubleshooting procedures.
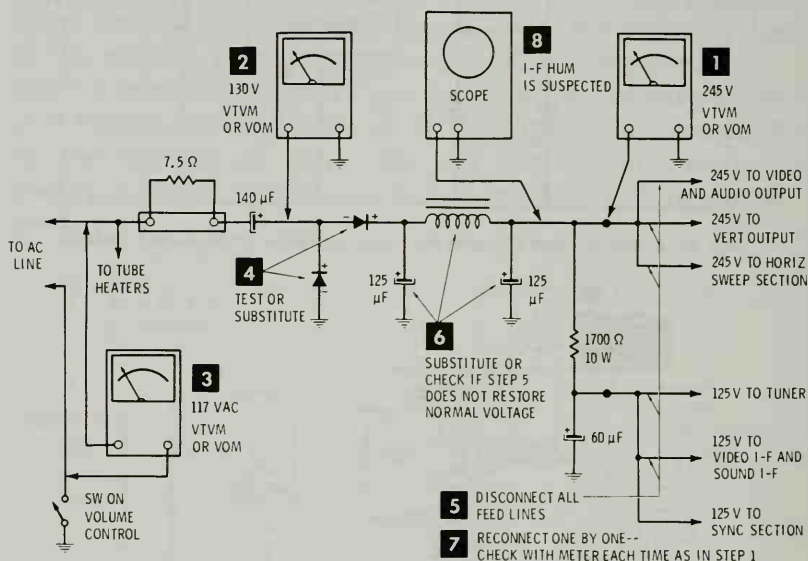
Fig. 19. Basic troubleshooting procedures for a semiconductor power supply.

SUMMARY

Power supplies in television receivers are generally more complicated than those normally used in radio and other electronic equipment. A low-voltage, high-current supply must be used to feed video IF, sound amplifier, and other similar stages where applied potential will not exceed 450 volts. In addition a high-voltage, low-current system is needed to supply the accelerating anode potential for the picture tube.

The introduction of semiconductor rectifiers offered an opportunity to simplify and lighten receivers by eliminating

the heavy and bulky power transformers. Some circuits have one disadvantage; the chassis is connected to one side of the power line. The user could receive a dangerous electrical shock between chassis and any grounded metal object.

The "flyback" system of obtaining high voltage is used in nearly all modern TV receivers. It uses a high-voltage pulse created in the output circuit of the horizontal amplifier during retrace. This high voltage is then fed to a rectifier, where it is rectified and filtered and becomes a high anode potential for the picture tube.

REVIEW QUESTIONS

1. What are the advantages in using semiconductors in the power supply?
2. What can be used in a power supply to eliminate electrical shock?
3. How many different types of high-voltage power supplies have been used in television receivers? Name them.
4. What are the voltage and current requirements for low-voltage power supplies? High-voltage?
5. What is the approximate high voltage potential in modern TV receivers?
6. What method is used in nearly all modern TV receivers to obtain high voltage?

Sound IF Amplifiers and Audio Detectors

The sound IF system of the television receiver is similar to the IF system of an FM radio receiver. Two major differences from the standard FM receiver will be noted:

1. The intermediate frequency for FM receivers has been standardized at 10.7 megahertz, whereas the sound IF for intercarrier television receivers has been standardized at 4.5 megahertz. (This is the frequency difference between the video and sound carriers and is held constant at the transmitter.)

2. The deviation of the television sound carrier for maximum modulation has been established at 25kHz (a total sweep of 50kHz), whereas the maximum deviation for standard FM broadcasting has been set at 75kHz (a maximum sweep of 150kHz). Because a lower deviation is employed for television sound, a narrower passband can be used for the television sound IF system, and a shorter linear region can be used for the detector. The passband of a typical intercarrier sound IF amplifier is about 150kHz, and the linear region of the detector usually does not exceed 100kHz. A high-quality FM receiver might have an IF passband of 300 kHz and a linear range in the detector of as much as 2 megahertz.

A typical intercarrier sound-IF stage has a voltage gain of 100 times. If the stage is operated as a limiter, its gain is

approximately 5 times. Note that the over-all gain from the RF tuner to the FM sound detector is approximately the same as the over-all gain from the RF tuner to the picture detector. In other words, the sound-IF amplier compensates for the reduced amplification of the sound signal through the video-IF amplifier. Unlike the video-IF amplifier, automatic gain control is not used in the intercarrier sound-IF amplifier. That is, the sound-IF section operates at maximum gain, regardless of the incoming signal strength. A limiter stage operates as a peak clipper. In turn, little change in sound volume is normally observed from strong-station reception to weak-station reception. However, the sound output may become slightly noisy or "buzzy" if the incoming signal is very weak. Adequate sound output is normally obtained although the picture signal is so weak that the image is barely visible in the snow interference. Of course, in case of sound-IF or FM-detector malfunction, the situation may be reversed—little or no sound output may be present although the picture display is normal.
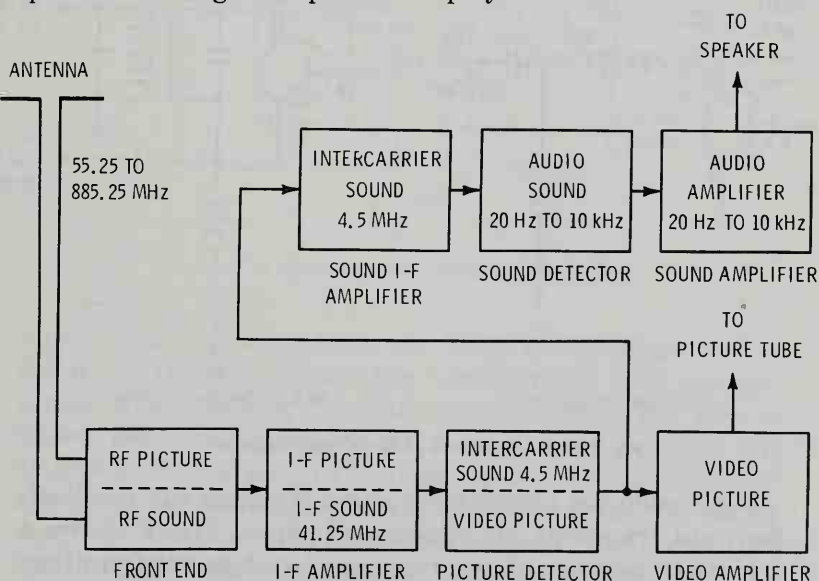
Fig. 1. Sound take-off point after the picture detector.

SOUND IF TAKE-OFF

The take-off point in an intercarrier receiver must follow the video detector. A sound detector requires a definite amount of signal to provide a noise-free signal. The amplification this signal receives is provided by the sound IF amplifier, the video amplifier, or combinations of both. The video IF amplifiers do not amplify the sound signal very much because the signal is attenuated in these stages.

The take-off point for most modern receivers is at the video-detector output (Fig. 1). The 4.5-MHz signal is coupled through a small capacitor from the video-detector output to the sound-IF amplier input. In other receivers, sound-IF take-off point is in the output circuit of the video amplifier to take advantage of the gain supplied by the video amplifier. Typical circuits are shown in Fig. 2.

(A) Capacitor coupling.   (B) Transformer coupling.
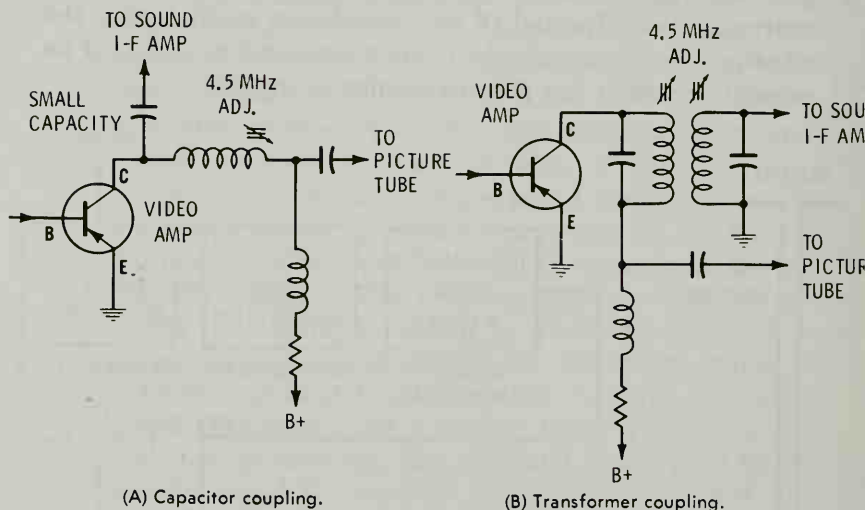
Fig. 2. Sound IF take-off points in video amplifier.

Semiconductor intercarrier sound circuitry can be classified into transistor and integrated types. Fig. 3 shows a typical transistor intercarrier sound-system configuration. In most transistor TV receivers, the 4.5-MHz intercarrier
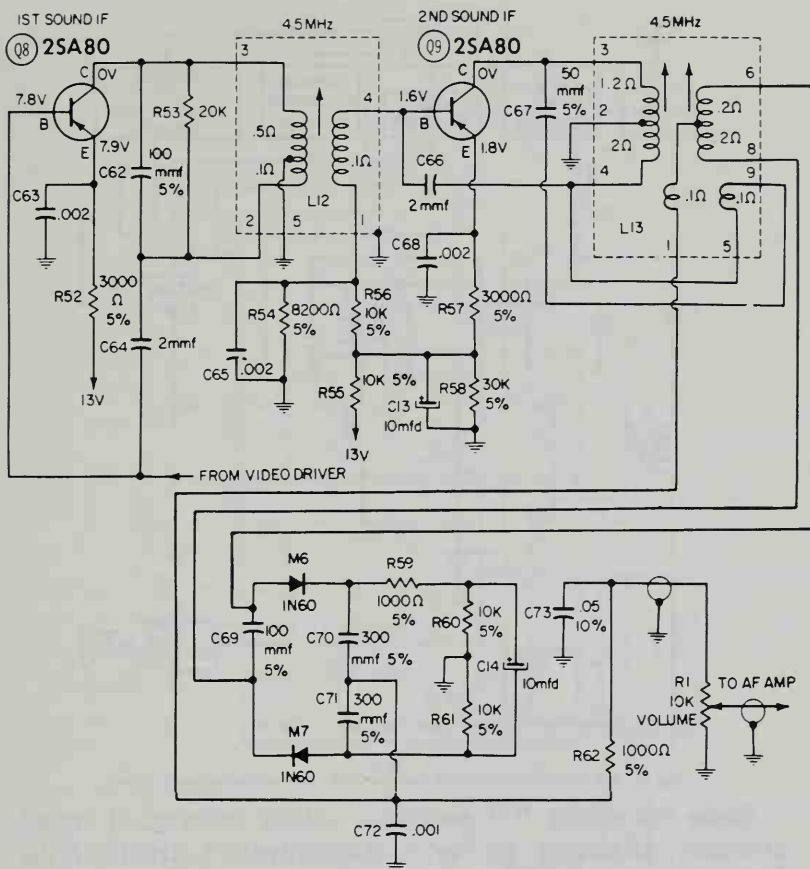
Fig. 3. A typical transistor sound IF configuration.

sound signal is taken from the video driver stage and is
the triode through C3 and the tuned circuit, they are pre-
vented from reaching the plate circuit because the tube is
biased near cut-off by the proper setting of control R2.
amplified in two sound-IF stages. The 4.5-MHz sound-IF
amplifiers can be compared with video-IF amplifiers, except
that the former have narrower passbands. Triode transistors
that require neutralization are commonly employed. For
example, C64 and C66 are neutralizing capacitors.

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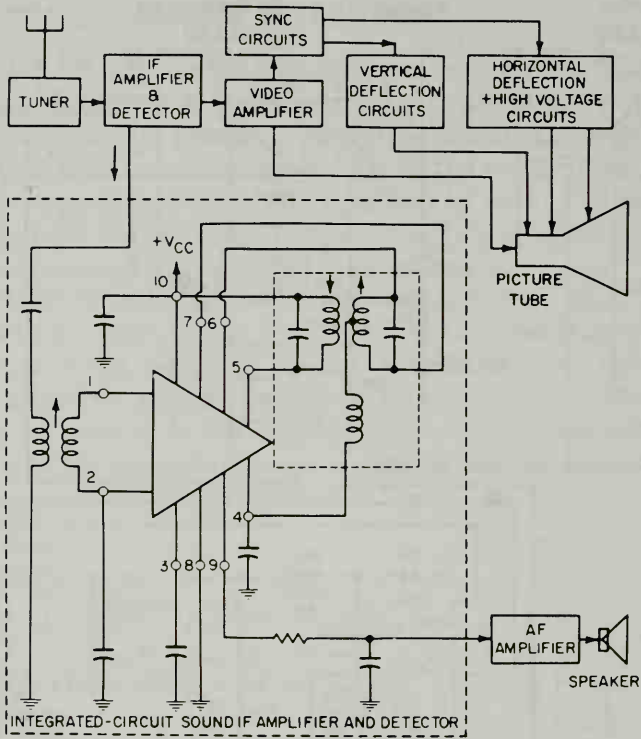
Fig. 4. An intercarrier sound system that uses an integrated circuit.

Some transistor TV receivers utilize integrated sound circuitry, as shown in Fig. 4. An equivalent circuit of the IC unit is seen in Fig. 5. This unit performs the functions
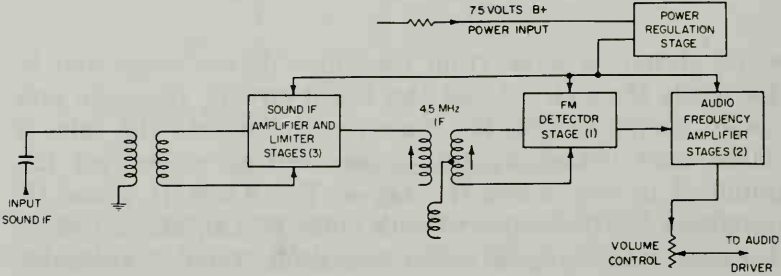
(A) Block diagram.

Fig. 5. Equivalent circuit of an integrated unit with
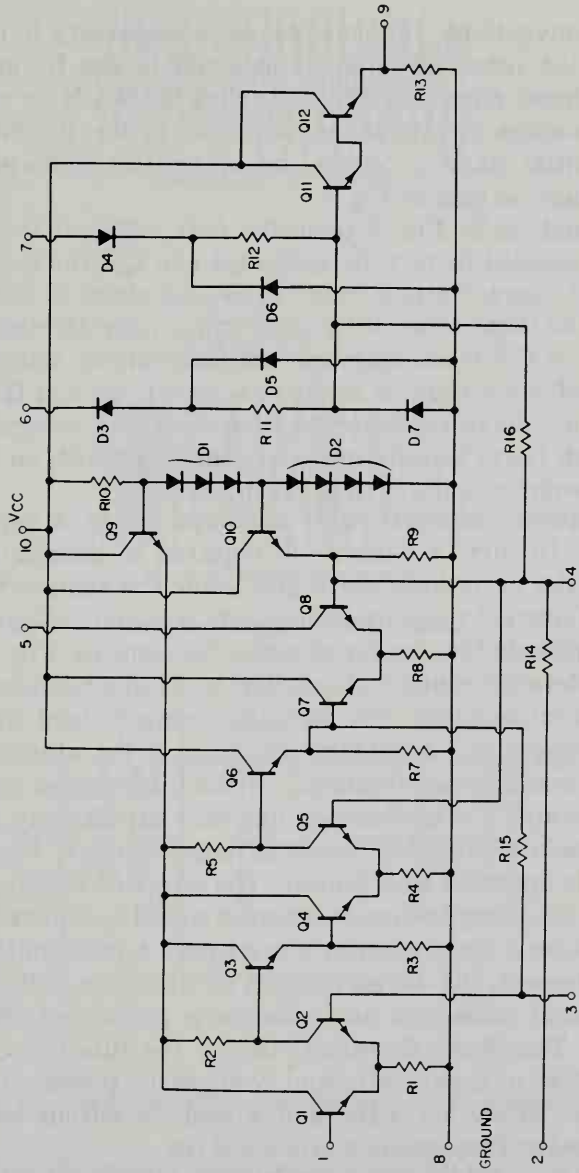
(B) Integrated circuit.

a block diagram showing the stages contained.

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of 26 conventional components. As is customary in most de-
signs, the tuned circuitry is external to the IC unit. The
tuned input circuit in Fig. 4 applies the 4.5-MHz signal to
a three-stage direct-coupled amplifier in the IC unit. Each
differential stage is coupled by an emitter follower to the
next stage, as seen in Fig. 5.

Q1 and Q2 in Fig. 5 form the first differential-amplifier
stage, coupled in turn by Q3 to Q4 and Q5, the second dif-
ferential stage. Output from the second stage is coupled by
Q6 to the third differential stage comprising Q7 and Q8. As
shown in the block diagram, the intercarrier sound signal
is transformer-coupled to the base of Q1. Q9 and Q10 oper-
ate in a voltage-regulator configuration. We recognize that
although fewer tuned circuits are employed with an IC unit,
more semiconductor devices are included.

Frequency modulation of a carrier wave is depicted in
Fig. 6. In turn, a detector is required to discriminate be-
tween the deviations above and below the center frequency
and to convert these deviations into a signal voltage having
an amplitude that varies at audio frequencies. Fig. 7 shows
a FM detector configurations that is called a balanced phase-
shift discriminator. The mutually coupled tuned circuits in
the primary and secondary windings of transformer T are
tuned to the center frequency of the intercarrier sound sig-
nal. Because a discriminator has very little ability to reject
amplitude modulation (such as noise pulses), the last IF
stage is operated as a limiter. The effect of limiting action
on the incoming intercarrier sound signal is depicted in Fig.
8. Because a discriminator circuit uses a push-pull rectifier
arrangement, the diodes conduct on alternate half cycles of
the signal waveform and produce a plus-or-minus output
signal. The phase characteristics of the tuned circuits are
such that a negative output voltage is produced at fre-
quencies below 4.5 MHz, and a positive output voltage is
produced at frequencies above 4.5 MHz.

Next, consider the ratio-detector circuit shown in Fig.
9. This configuration has a general resemblance to a dis-
criminator circuit, with an important difference. That is,

UNMODULATED RF CARRIER

AF MODULATING WAVE

FREQUENCY-MODULATED RF WAVE
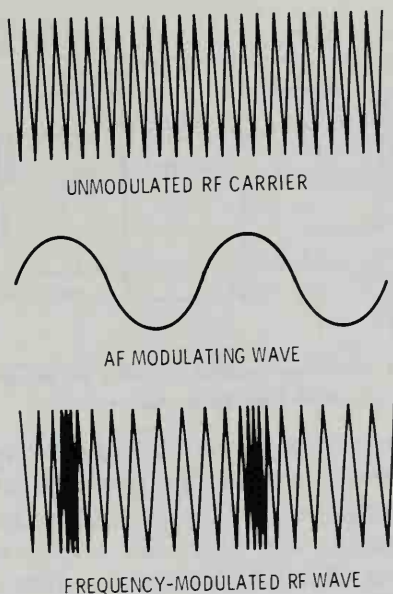
Fig. 6. Frequency modulator of a carrier wave.
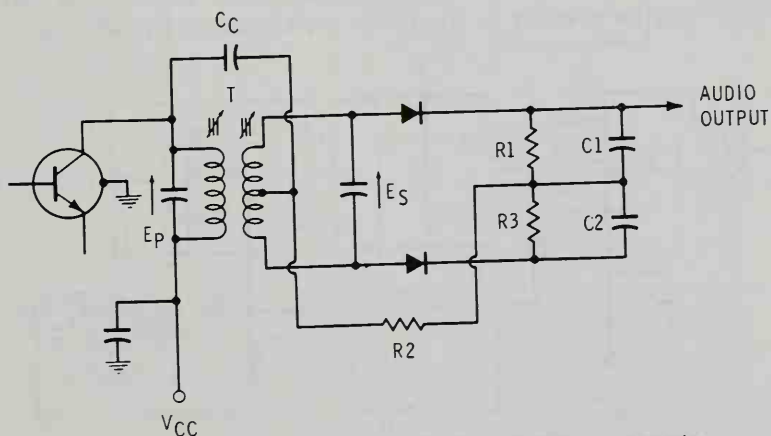
Fig. 7. Balanced phase-shift (Foster-Seeley) discriminator configuration.

the rectifier diodes are polarized oppositely. As will be explained, this feature provides considerable self-limiting action in the FM detection process. Therefore, receivers that
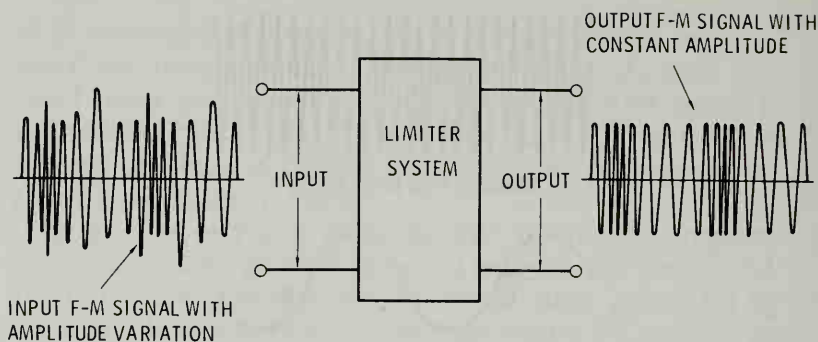
Fig. 8. A limiter is an overdriven amplifier that clips off the positive and negative peaks from the incoming signal.

use ratio detectors often do not operate the last IF stage as a limiter. In a ratio detector, the two rectifier voltages are added algebraically, and the sum is held constant by a large electrolytic capacitor, C3, which has a value of $5\mu F$ in this example. It is this effectively constant charge on the electrolytic capacitor that rejects amplitude variations in the signal—the large capacitor tends to absorb any peaks or valleys that may be present in the intercarrier-sound waveform.
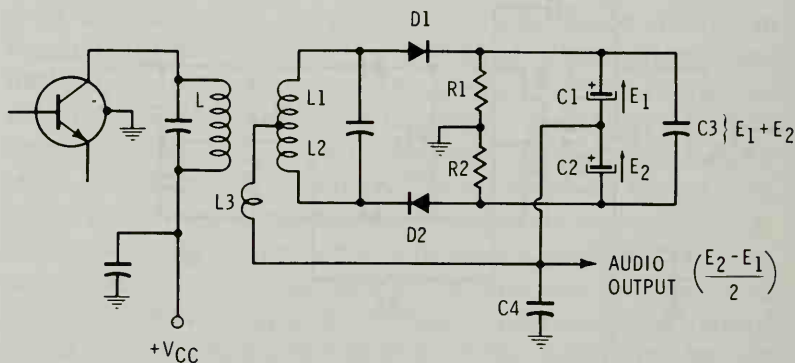
Fig. 9. A ratio-detector configuration.

Note that at the center frequency of 4.5 MHz, the voltage across C1 and C2 in Fig. 9 are equal and opposite, so that there is no output voltage. On the other hand, when the incoming signal swings below the center frequency, D2 con-

TUNER → SOUND I-F AMPLIFIER AND DISCRIMINATOR (R A) → AF AMP (R A) → TO SPKR

PICTURE I-F AMP (D HV) → PICTURE DETECTOR (R HV) → VIDEO AMPLIFIER DC RESTORER (R HV) → TO CR TUBE GRID OR CATHODE (R HV)

SYNC SEPARATION (R V) → VERTICAL OSCILLATOR AND AMP (R V) → TO VERT DEFLECTOR YOKE   HI-VOLT SUPPLY

(H R)

HORIZONTAL AFC CONTROL (R H) ← HORIZONTAL OSCILLATOR (R H) → HORIZONTAL OUTPUT AND DAMPER (R H) → TO HORIZ DEFLECTION YOKE

(H R)

HORIZONTAL OSC CONTROL (R H)   LOW VOLT SUPPLY

PROBE	SWEEP FREQUENCY
R DIRECT	H 7875 OR 15,750 Hz
D DEMODULATOR	V 20, 30, OR 60 Hz
	A AUDIO TEST FREQUENCY

Courtesy Heath Co.

Fig. 10. A simplified block diagram for a TV receiver showing basic oscilloscope test points.

ducts more than D1, and the output voltage swings negative. Conversely, when the incoming signal swings above the center frequency, D1 conducts more than D2, and the output

voltage swings positive. However, the voltage across C3 remains practically constant. It is helpful to note that the voltage across C3 tends to change somewhat from time to time, inasmuch as R1 and R2 function as bleeder resistors as well as load resistors. In practice, the change of voltage across C3 is more rapid for downward modulation of the incoming signal than for upward modulation. Since sync-buzz pulses produce downward modulation of the intercarrier signal (in most cases), the ratio detector may not be able to completely reject high percentages of sync-buzz noise. Therefore, when this is a problem in receiver operation, the last IF stage is operated as a partial limiter, or as a complete limiter.

TROUBLESHOOTING

At this point, it is helpful to consider and summarize some basic troubleshooting principles. A simplified block diagram for a TV receiver is shown in Fig. 10, with basic oscilloscope test points indicated. If the sound-IF amplifier and discriminator is checked with a sweep-frequency signal
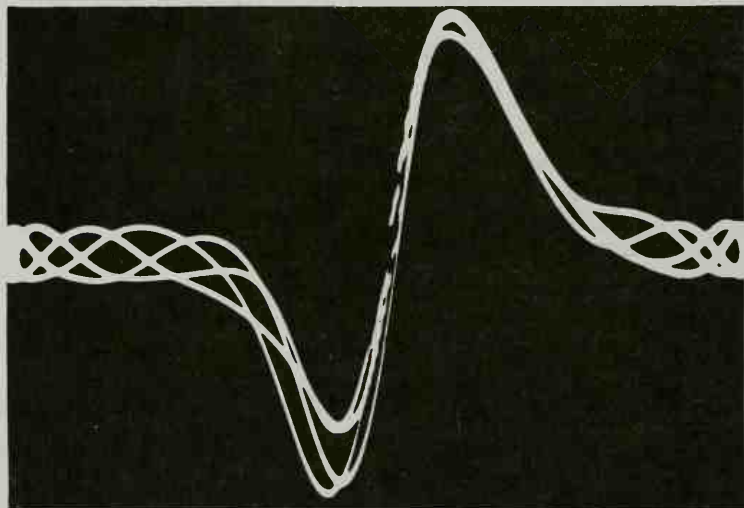
Courtesy Coyne Electrical School

Fig. 11. A normal S curve for a discriminator with an amplitude-modulated center-frequency beat marker.
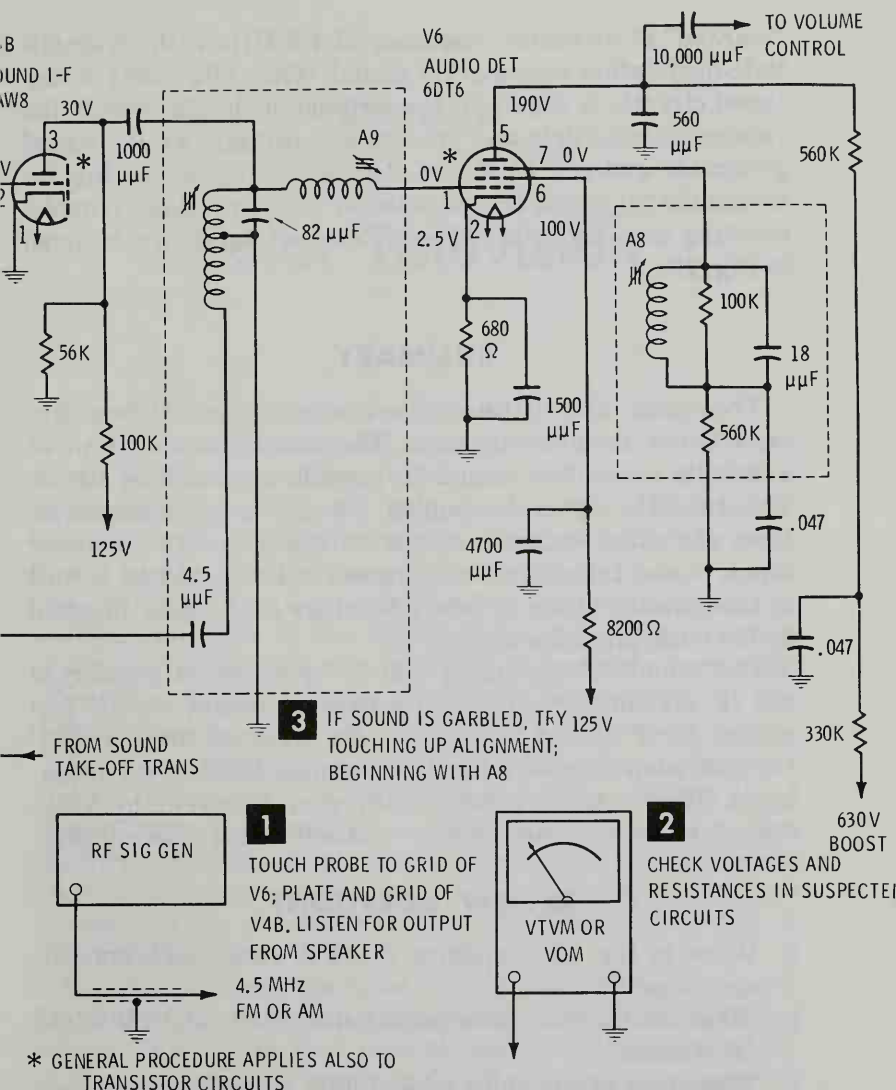
Fig. 12. Basic troubleshooting tests for sound-IF and detector stages.

having a center frequency of 4.5 MHz, the output waveform from the discriminator normally appears as illustrated in Fig. 11. Note that this is an "S" curve, and that it is being

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"marked" at its center frequency of 4.5 MHz with an amplitude-modulation beat-marker signal. When alignment of any tuned circuits is required, the technician should consult the receiver service data and proceed accordingly. An RF signal generator and a VTVM are also basic troubleshooting instruments for sound-IF and detector circuitry. Basic troubleshooting tests for sound-IF and detector stages are depicted in Fig. 12.

SUMMARY

The sound take-off for modern intercarrier TV receivers must follow the video detector. The sound detector requires a definite amount of signal to provide a noise-free signal. The 4.5-MHz signal is coupled through a small capacitor from the video detector output to the sound-IF amplifier input. Sound take-off point is generally in the output circuit of the video amplifier to take advantage of the gain supplied by the video amplifier stage.

The sound IF system of the TV receiver is similar to the IF system of an FM radio receiver except the IF frequency for FM is at 10.7 megahertz, whereas the sound IF for television receivers has been standardized at 4.5 megahertz. This is the frequency difference between the video and sound carriers and is held constant at the transmitter.

REVIEW QUESTIONS

1. What is the IF frequency for FM receivers? For TV receivers?
2. What are the main differences between FM and TV sound IF systems?
3. What part of the video IF amplifier is the sound take-off section?
4. What are the basic demodulation circuits used in television receivers? Name the circuits.
5. Explain the operation of the Foster-Seeley discriminator.

Color Television

The development of color television was governed by two requirements—the color signal had to be inserted within the 6-MHz channel bandwidth, and the color signal had to be compatible with the monochrome (black-and-white) television system. In other words, the signal must be such that it can be received on a monochrome receiver in black and white without any modification of the receiver. In addition, the part of the signal which conveys color must be transmitted in such a manner that it does not appreciably affect the quality or type of picture reproduced by the monochrome receiver which is tuned to the color signal.

The signal must represent the scene according to its color, and the colors must be transmitted in terms of the three chosen primaries—red, green, and blue. By some means, the three physical aspects of brightness, hue, and saturation must be conveyed by the signal for each color in the scene because the eye sees color in terms of these aspects. Fig. 1 shows the basic plan of the color-TV system.

In order to make the color system compatible, the specifications of the standard monochrome signal had to be retained. This meant that such things as the channel width of 6 megahertz, the aspect ratio of 4 to 3, the number of scanning lines per frame at 525, the horizontal-scanning and the vertical-scanning rates at 15,750 and 60 Hertz, respectively, and the video bandwidth of 4.25 megahertz had to remain the same within narrow tolerances. To these basic specifications, provisions' had to be added to convey the
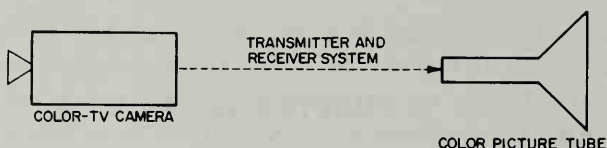
Fig. 1. Basic plan of the color-TV system.

color elements by means of a signal which will **hereafter be** known as the chrominance signal.

Even if the same specifications were retained, the color system would not be compatible if the composite color signal did not contain a signal which would convey brightness. To satisfy this requirement, a signal which is representative of the brightness of the colors in the scene must be transmitted together with the chrominance signal. This brightness signal is very much the same as the video signal used in standard monochrome transmission, and it will be referred to hereafter as the luminance signal. It is transmitted by amplitude modulation of the picture carrier in such a manner that an increase in brightness corresponds to a decrease in the amplitude of the carrier envelope.

Putting a chrominance signal in the allotted channel of 6-megahertz created a difficult problem, since this chrominance signal had to be transmitted along with the luminance signal and had to be included without objectionable interference to the luminance signal. This was accomplished by proper placement of the chrominance signal within the band of video frequencies and by limitation of the bandwidth nance signal had to be transmitted along with the luminance signal and had to be included without objectionable interference to the luminance signal. This was accomplished by proper placement of the chrominance signal within the band of video frequencies and by limitation of the bandwidth. The color signal carrier has the relations shown in Fig. 2 to the picture signal and the sound signal carriers.

The chrominance and luminance signals are included within the 4.25-MHz video band by an interleaving process. This process is possible because the energy of the luminance signal concentrates at specific intervals in the frequency

spectrum. The spaces between these intervals are relatively void of energy, and the energy of the chrominance signal can
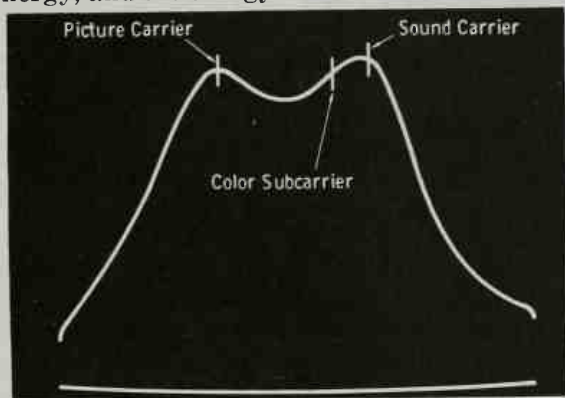
Fig. 2. An RF frequency response curve showing relations of the color, sound, and picture carriers.

be caused to concentrate in these spaces, as depicted in Fig. 3.

The chrominance signal is conveyed by means of a subcarrier. The frequency of this subcarrier was chosen so that its energy would interleave with the energy of the luminance signal. The energy of each of these signals is conveyed by the video carrier. The subcarrier frequency is high enough in the video band that the subcarrier sidebands, when they are limited to a certain bandwidth, do not interfere with the reproduction of the luminance signal by a monochrome receiver.

The chrominance signal must convey energy which represents the primary colors. Color could be transmitted by three separate signals each representing a primary color, but a channel width of at least 12.75 megahertz would then be required. Since this would take away the idea of compatibility, color had to be represented in some other manner in order to utilize the standard 6-MHz channel width.

Three signals—the red, the green, and the blue—are obtained from the camera. Portions of these three signals are used to form the luminance signal. This leaves three signals which are referred to as color-difference signals.

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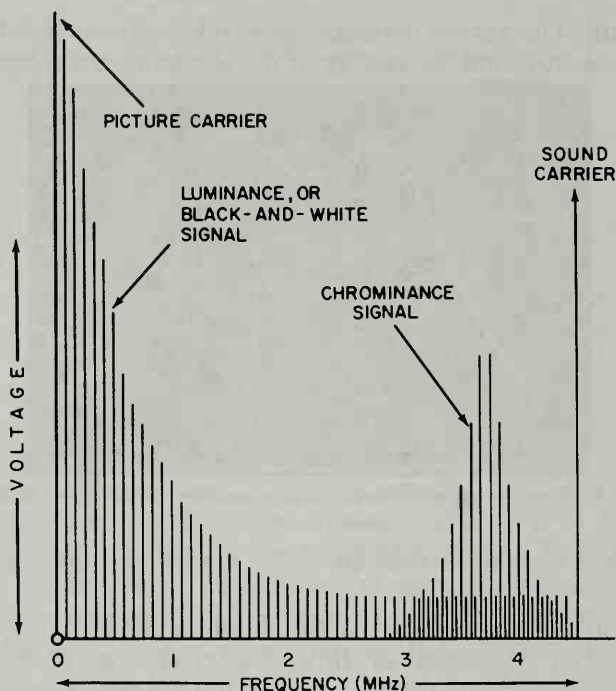
Fig. 3. Placement of the color signal.

Two of these are proportionately mixed together to form two other signals that are used to modulate the chrominance subcarrier.

A method of modulation known as divided-carrier modulation may be employed in order to place two different signals upon the same carrier. The subcarrier is effectively split into two parts, and each portion of the subcarrier is modulated separately. Then the two portions are combined to form the resultant chrominance signal. The amplitude and phase of this signal vary in accordance with variations in the modulating signals. A change in amplitude of the chrominance signal represents a change in color saturation, and a change in phase represents a change in hue.

A reference signal of the same frequency as the subcarrier frequency is transmitted in the composite color signal. This

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Fig. 4. The color burst is placed on the back porch of the horizontal sync pulse.
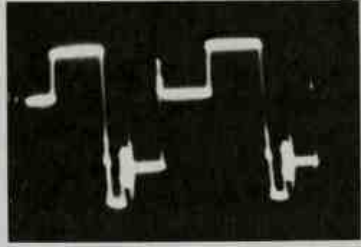
reference signal, called the color burst, has a fixed phase angle and is employed by the color receiver in order to detect properly the colors represented by the chrominance signal. Fig. 4 shows the appearance of the color burst. An expanded display of the color burst as obtained with a triggered-sweep oscilloscope, is shown in Fig. 5.

In the foregoing discussion, it has been stated that the composite color signal contains a luminance signal and a chrominance signal. A color-burst signal is also transmitted along with the conventional blanking and sweep-synchronizing signals. Let us now examine in greater detail the methods employed in making up the composite color signal.

CHARACTERISTICS OF COLOR

In order to see we must have a source of light, just as in the process of hearing, we must have a source of sound before we are able to hear. Obviously, if sound waves were not present, nothing would be heard. So, if a source of light were not present, nothing would be seen.

When we speak of light, we usually think of light coming from the sun or the light which is emitted from some artificial lighting source such as electrical lighting. This type of light is referred to as direct light. Another type of light is indirect or reflected light, which is given off by an object when direct light strikes it. The difference between these two types of light is that the indirect light is dependent upon the direct light. When light is not shining upon an

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object, light will not be given off unless the object contains self-luminating properties.

Direct light falling upon an object is either absorbed or reflected. If all of the light is reflected, the object appears white. If the direct light is entirely absorbed, the object appears black. The larger the amount of light that is reflected by an object, the brighter the object will appear to the eye. In addition, the more intense the direct light source, the brighter the object will become. This can be demonstrated by casting a shadow upon a portion of an object and noting the difference in brightness of the two areas. The portion without a shadow will, of course, appear brighter.

Light is one of the many forms of radiant energy. Any energy that travels by wave motion is considered radiant energy. Classified in this group along with light are sound waves, X-rays, and radio waves.
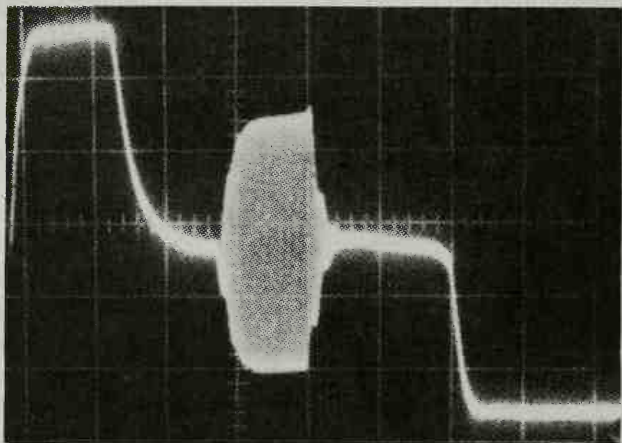
Fig. 5. An expanded display of the color burst as obtained with a triggered-sweep oscilloscope.

As shown in Fig. 6, light which is useful to the eye occupies only a small portion of the radiant-energy spectrum. Sound is located at the lower end of the spectrum, whereas cosmic rays are at the upper end. Light falls just beyond the middle of the spectrum. Along the top of the spectrum

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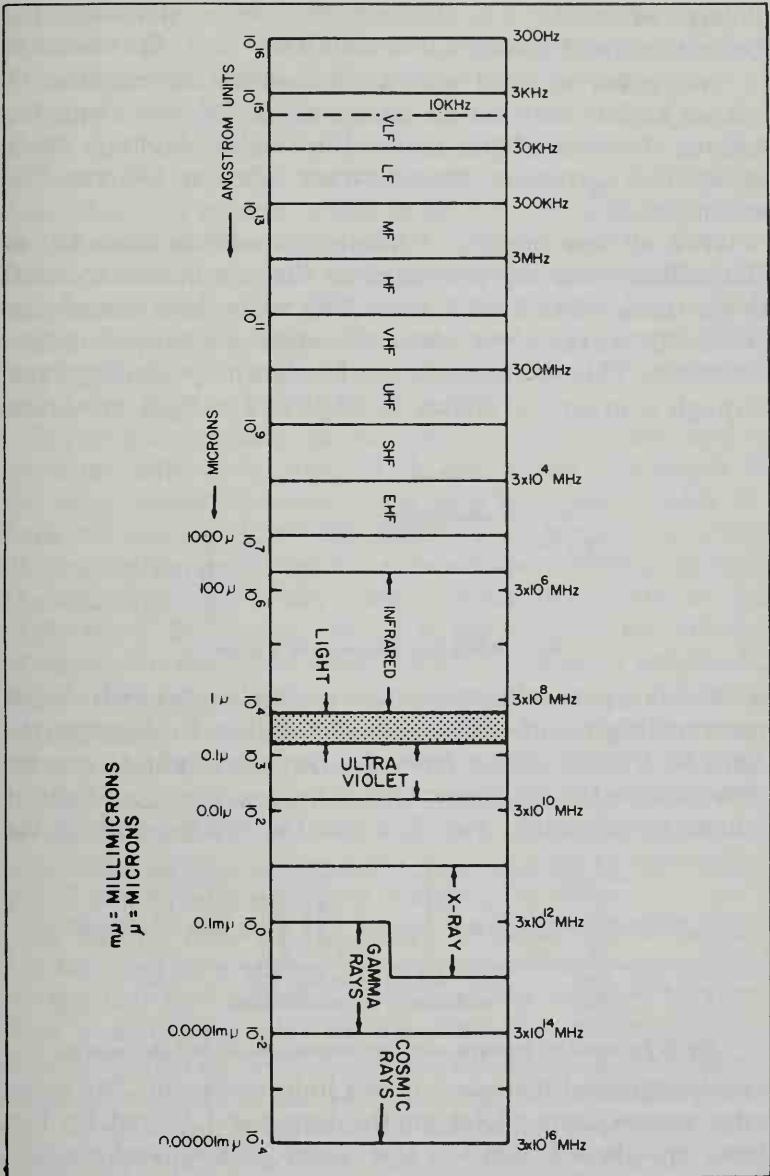
Fig. 4. Radiant-energy spectrum.

illustrated in Fig. 6 is the frequency scale, and along the bottom is the Angstrom-unit scale (10^{-8} cm). Wavelengths in the region of light may be designated in microns (1 micron $= 10^{-4}$ cm). These units are also shown along the bottom of the spectrum in the illustration. Light is made up of that portion of the spectrum between 400 and 700 millimicrons.

When all wavelengths of the light spectrum from 400 to 700 millimicrons are presented to the eye in nearly equal proportions, white light is seen. This white light is made up of various wavelengths which are representative of different colors. This composition can be shown by passing light through a prism, as shown in Fig. 7. The light spectrum
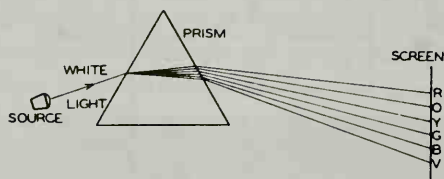
Fig. 7. White light dispersed by a prism.

is broken up into its constituent wavelengths, with each representing a different color. The ability to disperse the light by a prism stems from the fact that light of shorter wavelengths travels slower through glass than does light of longer wavelengths. Fig. 8 shows the relationship of the
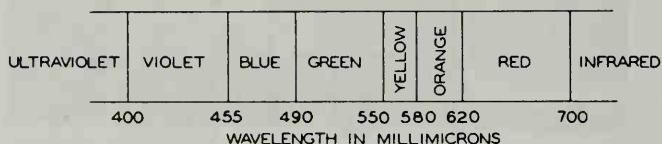
Fig. 8. Relationships between colors and wavelengths in the light spectrum.

wavelengths and the colors of the light spectrum. The spectrum ranges from violet on the lower end to red on the upper end. In between fall blue, green, yellow, and orange. A total of six distinct colors are visible when passing white light through a prism. Since the colors of the spectrum

pass gradually from one to the other, the theoretical number of colors becomes infinite. It has been determined that about 125 colors can be identified over the visible gamut.

There are three color attributes which are used to describe any one color or to differentiate between several colors. These are: (1) hue, (2) saturation, and (3) brightness. Hue is a quality which is used to identify any color under consideration, such as red, blue, or yellow. Saturation is a measure of the absence of dilution by white light and can be expressed with terms such as rich deep, vivid, or pure. Brightness defines the amount of light energy which is contained within a given color and can be expressed with terms such as bright, dark, or dim.

We might consider an analogy between a color and a radiated radio wave. Hue, which defines the wavelength of the color, would be synonymous with frequency, which defines the wavelength of the radio wave. Saturation, which defines the purity of the color, would be synonymous with the signal-to-noise ratio, which defines the purity of the radio wave. Brightness, which is governed by the amount of energy in the color, would be synonymous to amplitude, which defines the amount of energy in the radio wave.

Brightness is a characteristic of both white light and color whereas, hue and saturation are characteristics of color only.

Saturation and brightness are often visualized as identical or interrelated qualities of color, whereas they should be considered as separate qualities. It is possible to vary either one of these qualities without changing the other.

In nature, however, a change in saturation is usually accompanied by a change in brightness. This is exemplified by the fact that a pastel color generally appears brighter than a saturated color of the same hue when they are directly lighted by the same source. By changing the lighting on the pastel color (such as by placing it in a shadow), one can decrease the brightness of the pastel color; and it is conceivable that both colors can be made to have the same brightness. Thus, two colors of the same hue but of different saturation can have equal brightness levels.

Any given color within limitations can be reproduced or matched by mixing three primary colors. The additive process of color mixing used in color television employs colored lights for the production of colors. The colors in the additive process do not depend upon an incident light source. Self-luminous properties are characteristic of the additive colors. Phosphorescent signs which glow in the dark are good examples of this process. Cathode-ray tubes contain self-luminance properties, so it is only logical that the additive process would be employed in color television.

The three primaries for the additive process of color mixing are red, green, and blue. Two requirements for the primary colors are that each primary must be different and that the combination of any two primaries must not be capable of producing the third. Red, green, and blue were chosen for the additive primaries because they fulfilled these requirements and because it was determined that the greatest number of colors could be matched by the combination of these three colors.

The basic principle of the color-TV system is shown in Fig. 9. When the red camera is energized at the transmitter, the red gun in the color picture tube at the receiver is energized. Similarly, a signal from the blue camera results in an output from the blue gun; a signal from the green camera results in an output from the green gun. Since three kinds of signals must be transmitted in a channel which normally accommodates only one signal, a multiplexing or encoding method of transmission must be used. This involves modulating one carrier with two signals, as explained next.

DIVIDED-CARRIER MODULATION

It has been pointed out that for purposes of color transmission, a chrominance signal is required; moreover, the chrominance signal must represent two color signals (saturation and hue) separable from each other. One subcarrier at a frequency of 3.579545 megahertz above the picture

COLOR TELEVISION
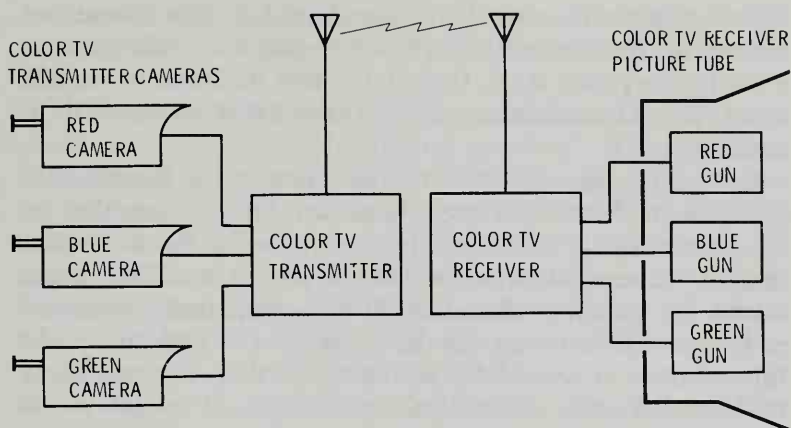
Fig. 9. Basic principle of the color-TV system.

carrier is available to convey both color signals. Consequently, some method of modulating one carrier with two signals must be utilized at the transmitter.

As can be seen in Fig. 10, a fundamental block diagram illustrates the manner in which one carrier may be modulated by two signals. A subcarrier generator produces a
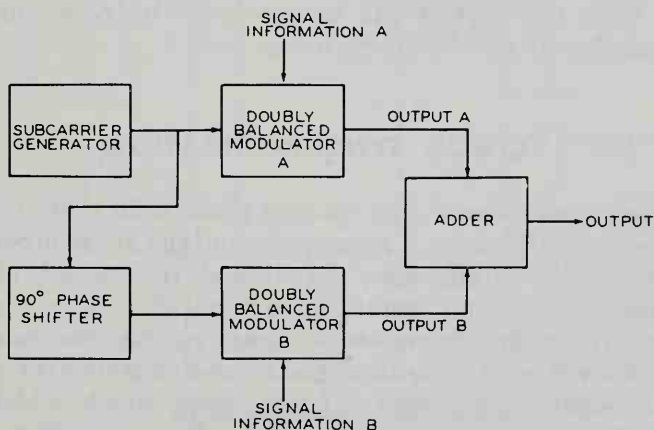
Fig. 10. Block diagram of divided-carrier systems of modulation.

sine wave of constant frequency and amplitude. This subcarrier is then applied to two doubly balanced modula-

tor circuits represented by blocks A and B. The subcarrier coupled to the modulator in block B has been subjected to a 90-degree phase shift. One of the two modulating signals is applied to modulator A, and the other is applied to modulator B.

In Fig. 10, there are two blocks representing doubly balanced modulators. The modulator in block B operates in the same manner as the one in block A, with the exception that the subcarrier input is delayed 90 degrees. This delay causes the output of modulator B to be displaced 90 degrees in phase with reference to the output of modulator A. In this respect, it should be remembered that the output of modulator B can either lead or lag that of modulator A by 90 degrees, depending upon the polarity of the modulating signal introduced into each balanced modulator circuit.

The voltages from the outputs of modulators A and B are combined in the adder stage. The output of this stage is a single waveform which varies in amplitude and phase in accordance with the amplitude and phase of each of the two signals introduced to modulators A and B. Thus, two modulating signals are impressed upon a single subcarrier, and these two signals can be recovered by reversing the modulation process at the receiving end.

COLOR SYNCHRONIZATION

The chrominance signal changes phase with every change in the hue of the color it represents, and the phase difference between the chrominance signal and the output of the subcarrier generator identifies the particular hue at that instant. When the chrominance signal reaches the receiver, the receiver must have some means of comparing the phase of the signal with a fixed reference phase which is identical to that of the subcarrier generator at the transmitter. This reference phase is provided in the receiver by a local oscillator which is synchronized with the subcarrier generator by means of a color-burst signal that is transmitted

during the horizontal-blanking period. The color burst consists of a minimum of eight Hertz at 3.579545 megahertz.

As shown in Fig. 11 the color burst is placed on the back porch of the horizontal-blanking pedestal. When located at this point, the burst will not affect the operation of the horizontal-oscillator circuits because the horizontal systems used in existing receivers are designed to be immune to any noise or pulse for a short time after they have been triggered. Remember, the horizontal oscillator will have been triggered at the start of the horizontal sync pulse. Since the average voltage of the color burst is the same as the voltage of the blanking level, the burst signal will not produce spurious light on the picture tube during the retrace period.

A color receiver is designed to extract the color burst from the transmitted signal. This reference signal is used
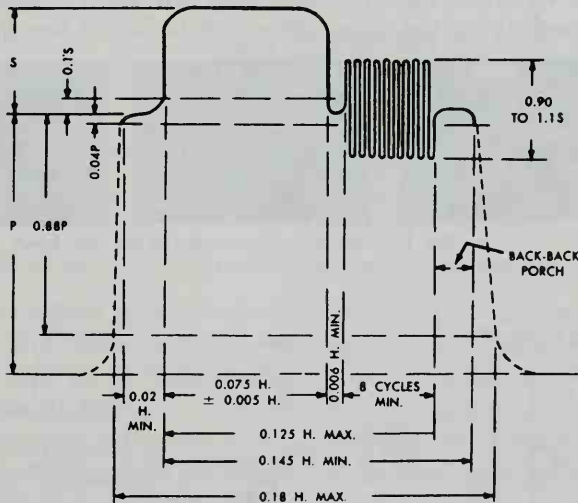
Fig. 11. Specification for the color burst.

to synchronize the color section of the receiver in much the same manner as the horisontal and vertical pulses are used to synchronize the horizontal-and vertical-sweep sections.

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If the color burst is attenuated, the receiver is likely to loose color sync lock. (See Fig. 12).

THE COLOR SIGNAL

As has been shown in the foregoing chapter, the color picture signal consists of two separate signals. These are a luminance signal and a chrominance signal. We will now discuss the make-up of these two signals at the transmitter.

Shown in Fig. 13 is a drawing of the basic components of a tricolor camera which employs three camera tubes and two dichroic mirrors for the separation of light. Regular image orthicons may be used in this camera; however, newer tubes which have a response to light frequencies more nearly like that of the human eye are also used. One of the camera tubes receives only the light frequencies corresponding to the color red and is called the red camera tube. Another tube receives only the light frequencies corresponding to the color blue and is called the blue camera
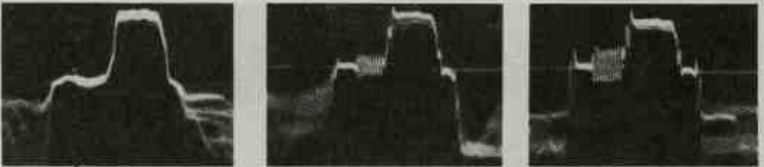
Fig. 12. Progressive attenuation of the color burst.
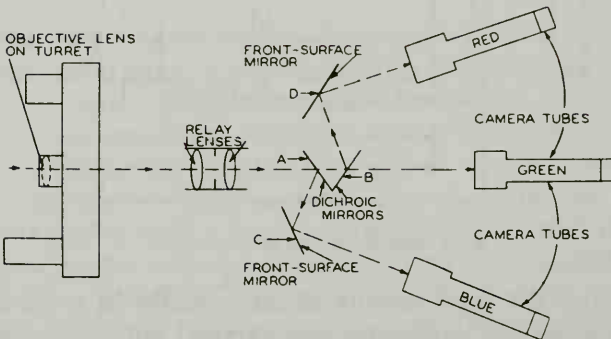
Fig. 13. Drawing of the basic components of a tricolor camera.

tube. The third tube receives only light frequencies corresponding to the color green and is called the green camera tube.

To illustrate the operation, let us assume that the color camera is focused on a color scene. The light is broken up in the following manner. All the light frequencies pass through the objective lens which is mounted on the turret and through a pair of relay lenses. Then the light is affected by the dichroic mirrors. This type of mirror permits all the light frequencies of the spectrum to pass except those of the primary color which it is designed to reflect. By the use of this type of mirror, white light can be separated into the light frequencies of the three primary colors—red, green, and blue. This principle is depicted in Fig. 14.
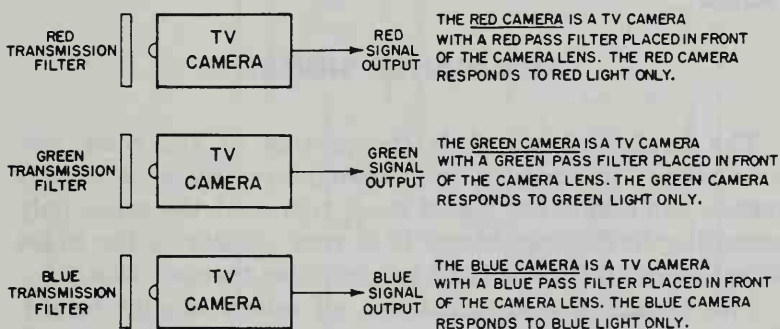
Fig. 14. Color filters permit only the primary colors to enter the color camera.

Through correct placement, only two dichroic mirrors are needed in the color camera. The blue dichroic mirror is positioned at a point indicated by A on the diagram. When light arrives at this point, all the light frequencies except those representing the color blue are passed through the mirror. The frequencies representing the blue portion of the spectrum are reflected. The tilt angle of the mirror at point A is such that the mirror directs the blue light to a front-surface mirror at point C. Then the blue light is reflected onto the face of the blue camera tube.

The light that was passed by the dichroic mirror at point A goes on to the red dichroic mirror which is positioned

at point B. This mirror is designed to pass all the light frequencies except those which represent red. The red light is reflected to a front-surface mirror at point D where it is again reflected so that it falls on the face of the red camera tube.

Both the blue and the red portions of the incoming light frequencies have been removed, and only the green portion remains. This is allowed to fall directly on the green camera tube. In this manner, the light is broken up into the three primary colors.

At the output of the color camera, there are three voltages which are representative of the three colors. From these voltages, the luminance and chrominance signals are formed. Fig. 15 shows the plan of a basic color-TV transmitter.

LUMINANCE SIGNAL

The luminance signal is the portion of the color picture signal utilized by monochrome receivers. For this reason, the luminance signal must represent the scene only according to its brightness. It is very similar to the video signal specified for standard monochrome transmission.

The human eye does not see all colors equally bright. The specifications for the luminance signal take into consideration the sensitivity of the eye to light frequencies. Definite proportions of each of the color signals from the color camera are used to form the luminance signal. These proportions are: 59 per cent of the green signal, 30 per cent of the red signal, and 11 percent of the blue signal. Fig. 16 provides a visualization of these facts.

If an all-white portion of a scene is being scanned at the camera, the luminance signal will contain these proportions of the three color signals. The luminance signal is commonly called the Y signal. The proportions of the red, green, and blue signals do not change when brightness changes, only the amplitude of the Y signal changes. Fig. 17 shows a display of the Y signal on an oscilloscope screen.
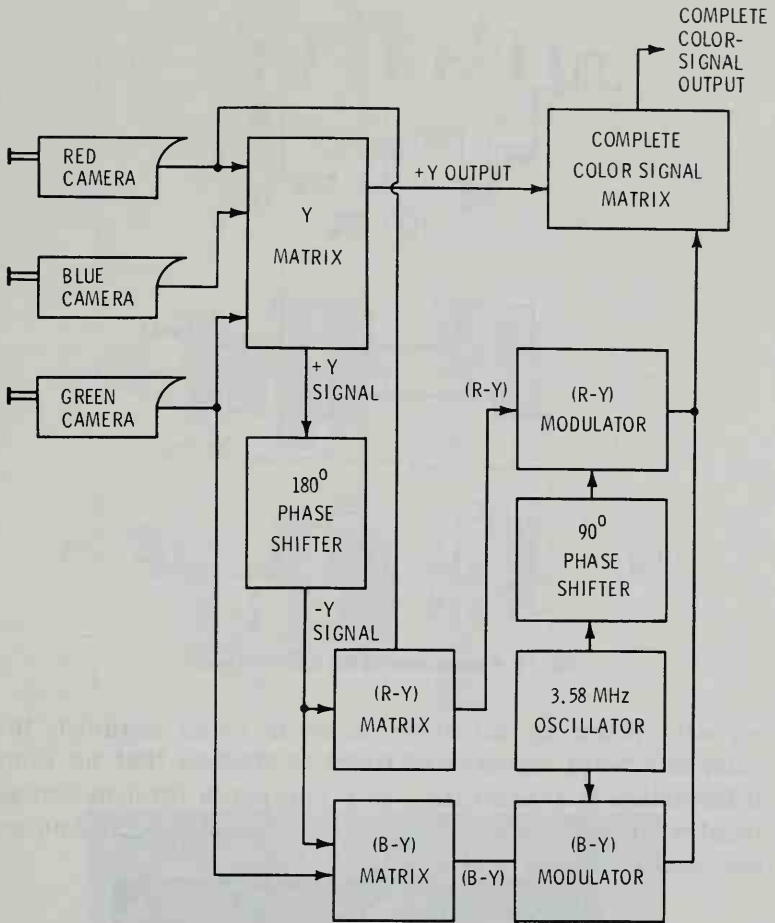
Fig. 15. Plan of a basic color-TV transmitter.

CHROMINANCE SIGNAL

The chrominance signal must represent only the colors of a scene; therefore, the luminance signal is subtracted from each of the three output signals of the color camera. This results in three signals which represent red minus luminance, green minus luminance, and blue minus luminance. These signals are denoted as the color-difference

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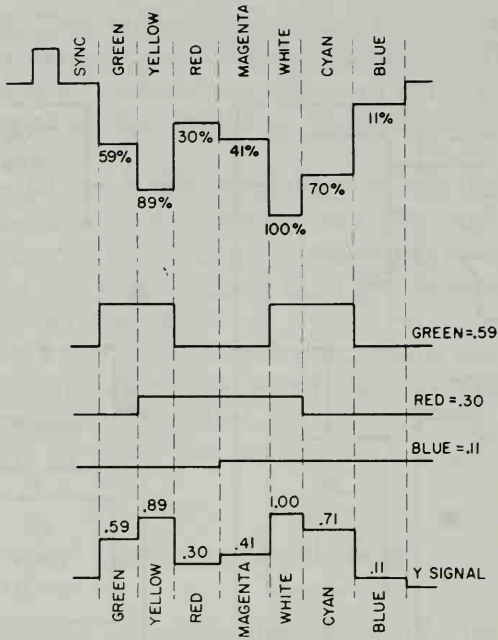
Fig. 16. Y component of the color-TV signal.

signals. When an all-white scene is being scanned, the color-difference signals are equal to zero so that no color information is transmitted, only luminance information as illustrated in Fig. 18. A display of a color-bar signal on an oscilloscope screen is shown in Fig. 19.
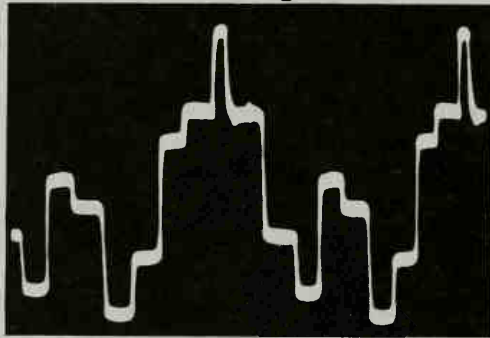
Fig. 17. Display of the Y-signal on an oscilloscope screen.
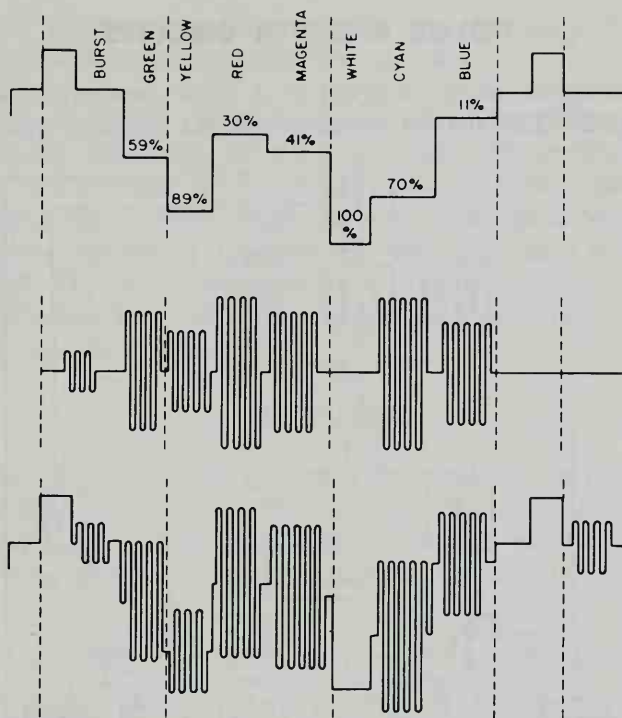
Fig. 18. Elements of TV color bars.
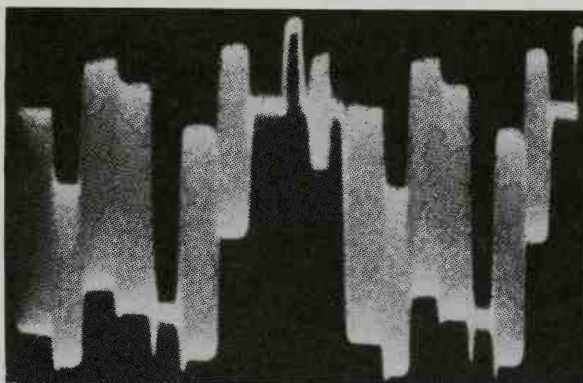
Fig. 19. Display of a color-bar signal on an oscilloscope screen.

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COLOR RECEIVER CIRCUITS

A complete block diagram of a color receiver is shown in Fig. 20. The shaded blocks represent sections which are
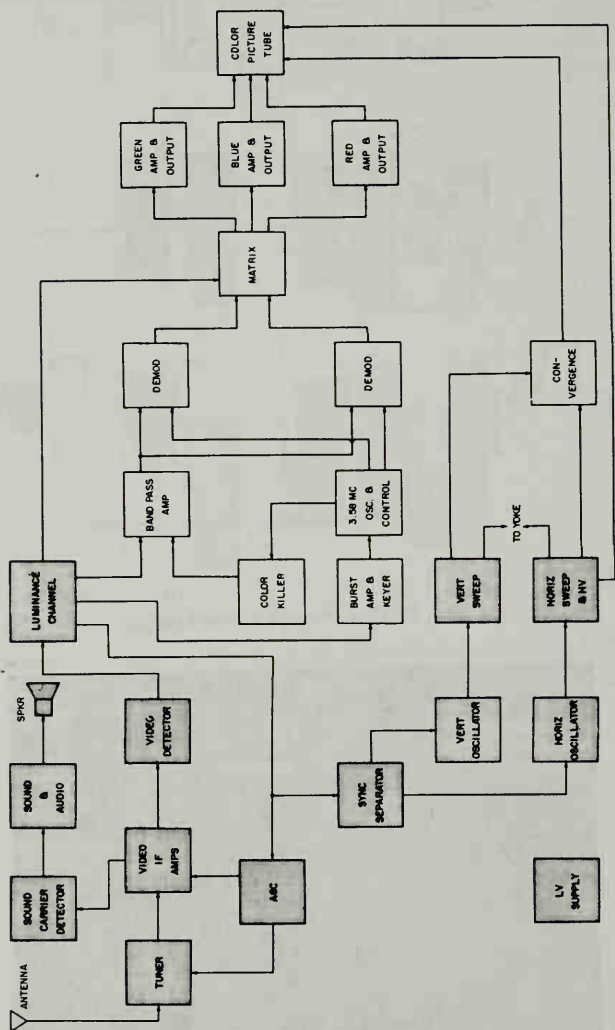
Fig. 20. Complete block diagram of a color receiver. Sections similar to those used in monochrome receivers are shaded. Sections used only in color receivers are unshaded.

similar to those used in monochrome receivers. The un-shaded blocks represent the new sections used only in color receivers.

From the block diagram in Fig. 20, it can be seen that the tuner, the video IF and the sound IF sections of a color receiver are not too much different from those of a monochrome receiver. With the exception of the block representing the sound detector, this drawing could represent the RF, IF, and sound circuits of any television receiver; nevertheless, the following discussions about circuits show some important differences.

RF TUNER

The function of the RF tuner in a color receiver is the same as in monochrome receivers, and the physical appearance of the unit has not changed; however, the RF circuits in a color receiver must have one feature that is not neces-
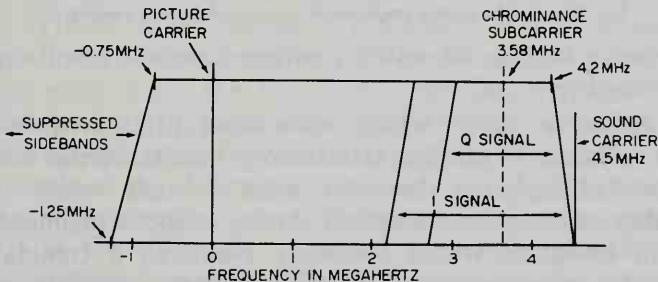
Fig. 21. Frequency distribution of the color picture signal.

sarily required of the RF circuits in monochrome receivers. This concerns the allowable tolerance in the frequency response of the tuner.

It has been previously pointed out that a color picture signal comprised of both a luminance and a chrominance signal. As seen in Fig. 21, the bandwidth of this signal extends from 0.75 megahertz below to 4.2 megahertz above the picture carrier and falls to zero at 1.25 megahertz below and at slightly less than 4.5 megahertz above.

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If a tuner designed for a monochrome receiver were to be used in a color receiver, nonuniform amplification of frequencies might result and cause poor color reception. Although a tilt or sag in the response of the RF tuner might be compensated for in the IF amplifier section, it is necessary to provide uniform bandpass characteristics in the tuner for proper reception of color telecasts on all channels. An RF circuit which has a frequency response similar to
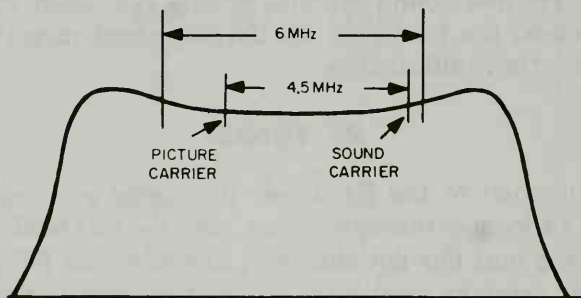
Fig. 22. Ideal frequency response of tuner used in color receiver.

that shown in Fig. 22 would produce excellent results in a color receiver.

A defective tuner which attenuates high frequencies might continue to provide satisfactory results during monochrome transmission; however, such a tuner would very probably cause poor reception during color transmission. Such a condition would obviously result in a complaint. When the tuner in a color receiver is being serviced, particularly during alignment, the bandpass requirement of the tuner must be kept in mind. Many of the compromises which are in common practice in servicing tuners for monochrome receivers cannot be made in tuners for color receivers.

VIDEO IF AMPLIFIERS AND VIDEO DETECTOR

Although the bandpass characteristics of the video IF section are more restrictive in a color receiver, the function is essentially the same as in monochrome receivers. Before

examining any circuits, let us consider what is required of the video IF section.

First of all, the purpose of this section is to provide amplification and selectivity to a specific band of frequencies. This band should extend from .75 megahertz below to around 4.2 megahertz above the IF picture carrier in order to include both the luminance signal and the chrominance signal. Ordinarily, four or five stages are needed for this function. The video IF strip should also attenuate the sound IF carrier much more severely than is common in monochrome receivers. An interference pattern will appear on the screen if the sound carrier and color subcarrier are allowed to beat together.

A curve illustrative of good over-all frequency response through the RF and IF sections of a color receiver can be seen in Fig. 23A. Compare this curve to the one in Fig. 23B which is representative of the over-all frequency response of late-model monochrome receivers. It can be particularly noted that the response of the color receiver is very critical in the region of the sound carrier where the slope of the curve is very steep. Frequencies only .35 mega-Hertz away from the maximum attenuation point at the sound-carrier frequency are provided with at least 90-per cent amplification. The reason for this is that the upper sidebands of the chrominance subcarrier extend to this portion of the frequency curve. To illustrate this, the frequency limits of the color picture signal have been superimposed on the response curve of Fig. 23A. Although the frequency response indicated by the curve in Fig. 23B would produce good results during a monochrome transmission, it would severely attenuate the chrominance signal during color transmission. This loss of chrominance would result in poor color reproduction or a complete loss of color.

The video detector demodulates the IF signal so that the luminance, chrominance, and sync signals are available at the output of the detector circuit. A crystal diode with an IF filter is commonly used for this purpose. The video detector in a color receiver may employ a sound-carrier trap in its input. This trap attenuates the sound carrier and

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(A) Color receiver.

(B) Late-model monochrome receiver.
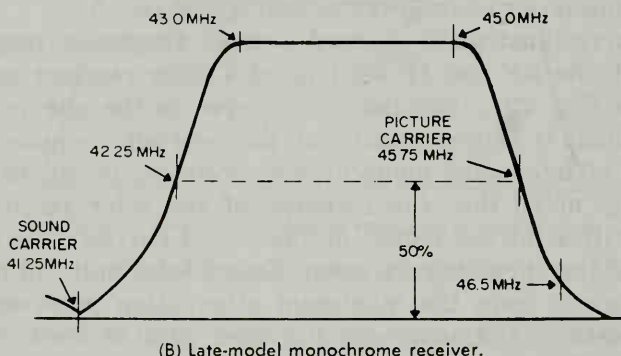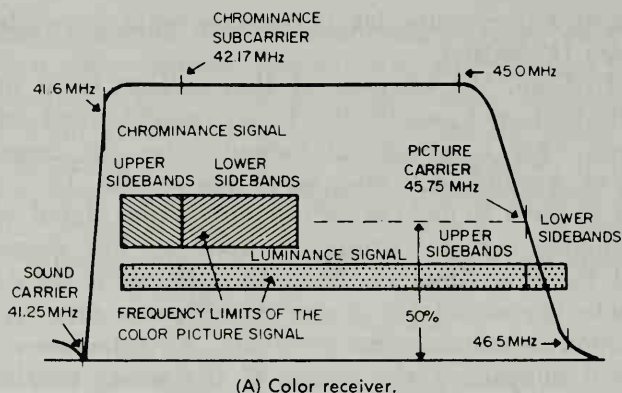
Fig. 23. RF and IF frequency-response curves.

insures against the development of an undesirable 920 kHz beat frequency which is the frequency difference between the sound carrier and the color subcarrier. When the sound carrier is attenuated in this manner, the sound take-off point is located ahead of the video detector.

A basic IF amplifier configuration is shown in Fig. 24. The third IF transistor operates at higher power than the other two transistors because the video detector requires appreciable power input. Transistor Q25 operates with a collector voltage of 15 volts and an emitter current of 15 mA. The collector load impedance is about 1000 ohms; however, T8 provides some step-up voltage transformation for the video detector. The power gain of this stage is about 18 dB.
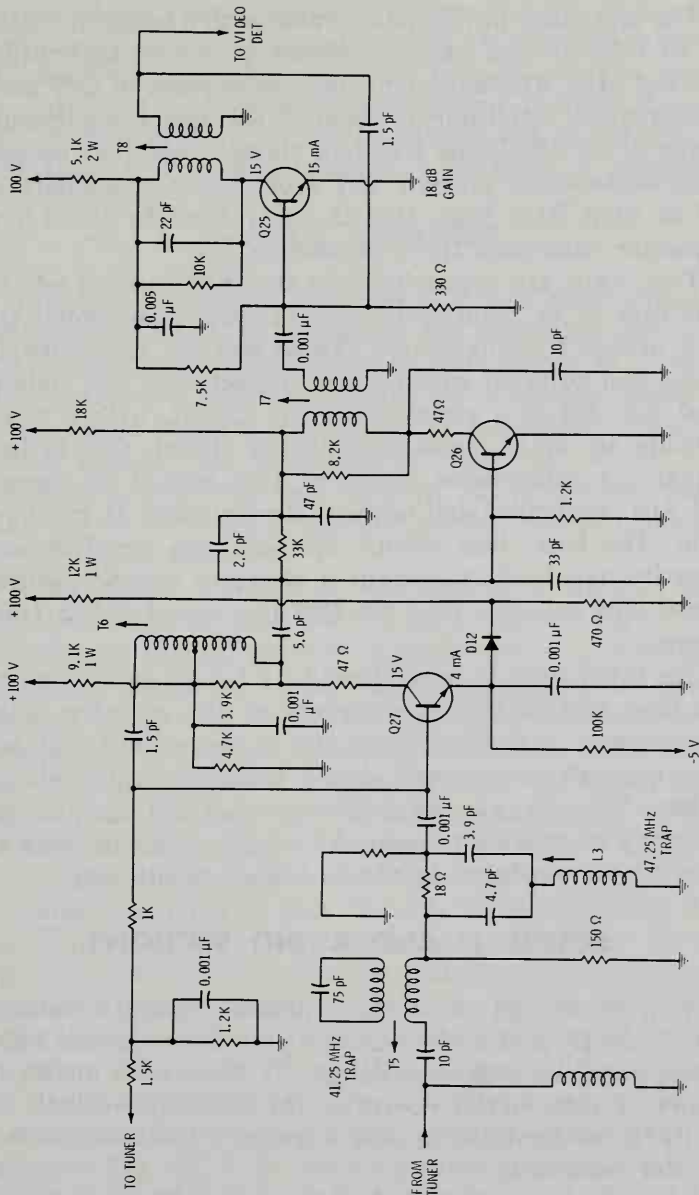
Fig. 24. Typical video-IF amplifier configuration.

The first stage in Fig. 24 operates with a collector voltage of 15 volts and an emitter current of 4 mA. Q27 utilizes reverse AGC. The minimum collector current of Q27 under strong signal conditions is about 50 μA. Q27 has a dynamic range of 40 dB. Diode D12 is a clamp diode that becomes reverse-biased to prevent Q27 from being completely cut off at high AGC bias. Q27 is neutralized by the 1.5 pF capacitor connected from its base to T6.

Two traps are connected into the input circuit of Q27. The first is an inductively coupled trap. The second trap is a bridge-T configuration. These are the accompanying sound and adjacent sound traps, respectively. The collector load for Q27 is a simple resonant circuit, with a tap to provide an out-of-phase neutralizing signal. Q26 is base-driven via capacitance coupling. This second IF stage is not AGC controlled and operates continuously at maximum gain. The basic bias circuit for Q26 also provides some negative feedback, to obtain a properly shaped response curve. The collector load for Q26 is a tuned bifilar transformer.

The third stage is neutralized by a 1.5 pF capacitor from the base of Q25 to the secondary of the collector output transformer. A 0.005 μF capacitor is connected in the base bias network to prevent signal feedback from collector to base. This stage is not AGC controlled and operates continuously at maximum gain. All of the collector loads are shunted by resistance to obtain proper bandwidth.

SOUND IF AND AUDIO SECTIONS

With the exception of the separate sound IF detector, the sound IF and audio sections of color receivers follow conventional monochrome design. If the reader knows the theory of intercarrier operation, he should have little difficulty in understanding and working with these sections in color receivers.

It has been mentioned that the sound IF carrier is severely attenuated in the video IF strip; consequently, the

output of the video detector contains virtually no 4.5-MHz beat signal. The sound signal must be obtained from a point ahead of the video detector. This take-off point is usually the output of the final video IF amplifier. The signals available at this point are in the IF range; and in order to obtain the 4.5-MHz sound signal, a detector is necessary.

VIDEO AMPLIFIER

The main function of the video amplifier, often called the luminance channel, is to amplify the luminance portion of the video signal. This signal is comparable to a monochrome signal in that it represents the brightness variations of the image. From this standpoint, the function of the luminance channel can be compared with that of the video amplifier in a monochrome receiver. The luminance channel may use two or three stages so that the desired brightness signal may be obtained.

A secondary function of the luminance channel is to introduce a specific time delay in the brightness signal. This is necessary because all video signals undergo a time delay in reverse proportion to the bandpass limits of the circuits through which they pass. The time delay increases as the bandpass is narrowed. Since the luminance channel must pass a wider range of frequencies than the chrominance channel, the bandpass of the luminance channel is much wider than that of the chrominance channel. Were it not for a special design, it would take a longer time for the chrominance signal to pass through the chrominance channel than it would for the luminance signal to pass through the luminance channel. The associated picture elements of these two signals must arrive at the picture tube at the same time; therefore, the luminance signal must undergo an extra time delay. This delay is accomplished through the use of a special delay circuit in the luminance channel.

A typical direct-coupled video-amplifier configuration is shown in Fig. 25. A DC coupling diode is employed in the output stage. This diode tends to compensate for the drooping transfer characteristic of the output transistor when

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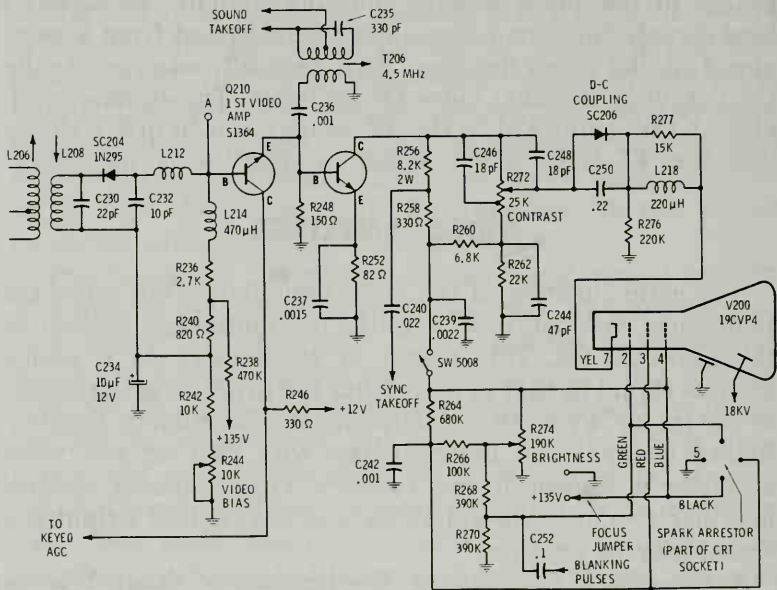
Fig. 25. A typical video-amplifier configuration.
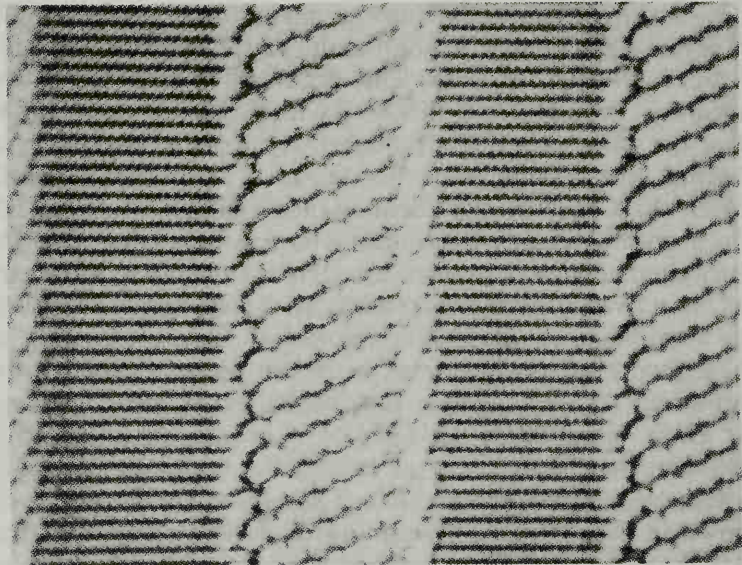
Fig. 26. The "wormy" effect produced by 920-kHz interference.

driven to maximum output. Blanking pulses are applied to the picture tube via C252. SC204 is the video detector and is followed by a low-pass filter comprising C232, L212, base input capacitance of Q210, and L214. This low-pass filter removes IF feedthrough and also serves a peaking function. The first stage operates in the common-collector mode, and provides an impedance match to the output stage. This output stage operates in the common-emitter mode. T206 serves both as a sound-takeoff transformer and as a 4.5-MHz sound trap for the video amplifier. Note that 4.5-MHz interference causes sound "grain" in the picture, and a combination of 4.5 MHz and 3.58-MHz interference produces a 920-kHz beat—a wormy effect that has the characteristic appearance shown in Fig. 26.

THE AGC CIRCUIT

Although conventional in operation, the AGC circuit plays an important part in the color receiver. This importance can be realized when it is considered that variations in the amplitudes of the incoming signal will affect the color as well as the brightness of the image. In order to stabilize the operation of the receiver, a good AGC circuit is a necessity.

The preceding material described the color receiver circuits which correspond very closely to those found in monochrome receivers. We will now discuss the circuits which deal with the proper reproduction of color. These circuits are represented by the unshaded blocks in Fig. 13.

In order to be utilized in the color receiver, the chrominance signal which is in the form of a 3.58-MHz signal must first be separated from the composite color signal. An amplifier stage having a frequency-limiting filter network is used for this purpose. This stage is called the bandpass amplifier. The chrominance signal is fed from the bandpass amplifier to two demodulators where two color-difference signals are extracted from the 3.58-MHz signal. In order for the latter function to take place, two continuous-wave (CW) signals

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are required by the demodulators. These CW signals are generated and controlled by a section referred to as the color-sync section of the receiver. A burst amplifier, a keyer, a 3.58-MHz oscillator, and a control circuit are used in the color-sync section.

During the reception of a monochrome signal by the color receiver, a means of cutting off the chrominance channel is provided. This function is performed by the color-killer section which automatically disables the chrominance channel when there is no color signal being received.

BANDPASS AMPLIFIER

The purpose of the bandpass amplifier is to separate the chrominance signal from the composite color signal and feed it to the demodulators. The signal at the take-off point for a typical bandpass-amplifier section is the composite color signal which includes the chrominance, luminance,
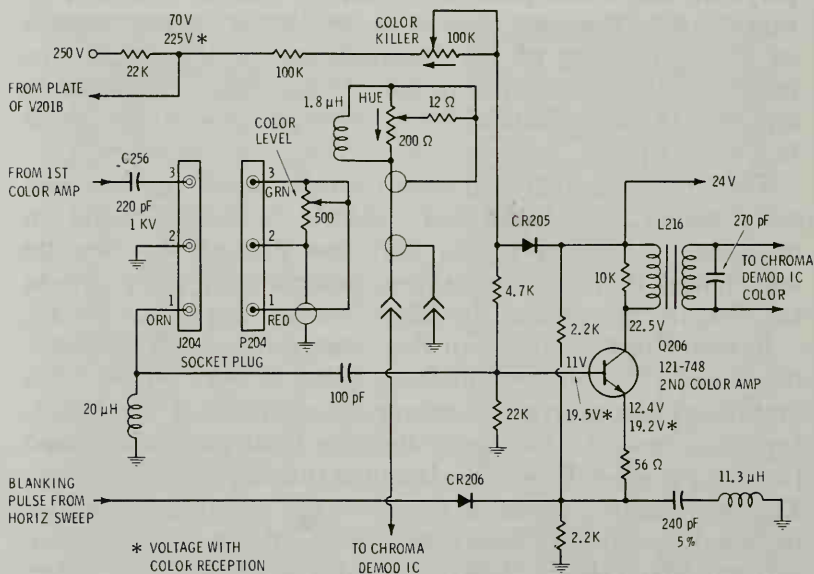
Fig. 27. A bandpass amplifier configuration.

burst, synchronizing, and blanking signals. The take-off point for the chrominance signal is usually in the first video amplifier stage but, depending on the gain in the bandpass amplifier, can be anywhere in the video section.

Only the chrominance portion of the composite color signal appears at the output of the bandpass-amplifier circuit. Between the signal take-off point and the input of the demodulators, any remaining 4.5-MHz signal has been attenuated, the luminance signal has been blocked, and the color-burst and synchronizing signals have been keyed out.

A typical bandpass amplifier configuration is shown in Fig. 27. Diode CR205 functions as a bias-voltage regulator for Q206 to compensate for temperature drift. Diode CR206 operates as a rectifier to ensure that only a positive-going pulse is applied to the emitter of Q206 for blanking the chroma signal during horizontal retrace. Note that base and emitter voltage for Q206 are specified for both conditions of color reception and of black-and-white reception. This change in base and emitter voltage is produced by color-killer action and often provides useful clues when troubleshooting bandpass amplifier malfunctions.

Fig. 28 shows the frequency response curve of a typical bandpass amplifier.
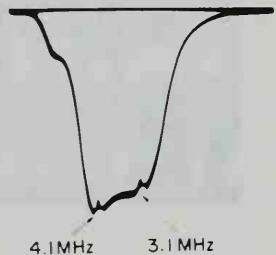
Fig. 28. Frequency response curve of a typical bandpass amplifier.

4.1MHz   3.1MHz

The setting of the COLOR control in the bandpass amplifier determines the amount of chrominance signal applied to the demodulators and also determines the saturation of the colors in the picture. This chrominance signal is coupled to the demodulator stages where it is detected. The chrominance signal varies in both phase and amplitude. It is the function of the demodulator stages to detect correctly the

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differences between the phase and amplitude of the chrominance signal in order for the receiver to reproduce the proper colors.

Normal input and output waveforms for the bandpass amplifier are shown in Fig. 29. The input waveform is a keyed-rainbow signal; it consists of a series of color bursts at a frequency of 3.56 MHz. Horizontal sync pulses are included in the keyed-rainbow signal. After this standard test signal is processed through the bandpass amplifier, the bursts appear in amplified form, with the horizontal sync pulses keyed out. Keyed-rainbow generators are discussed in a following chapter.
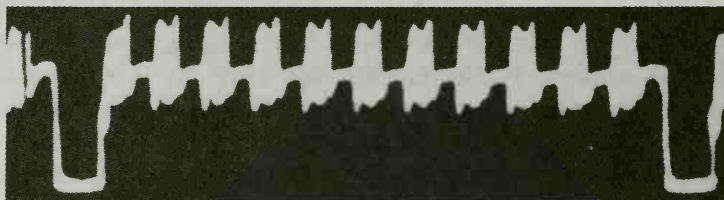
(A) Input.
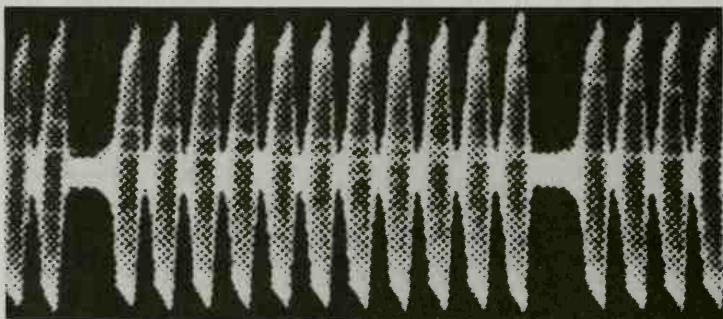
(B) Output.

Fig. 29. Input and output waveform for the bandpass amplifier.

Let us briefly review how the color signal varies in phase and amplitude. Fig. 30 shows how the primary colors (red, green, and blue) and how the complementary colors (magenta, cyan, and yellow) have different amplitudes and phases. The burst phase is at 0°. In turn, yellow has a phase angle of 12°, red has a phase angle of 76.5°, and so on. The

relative amplitudes of yellow and red are 45% and 63% with respect to the amplitude of white.
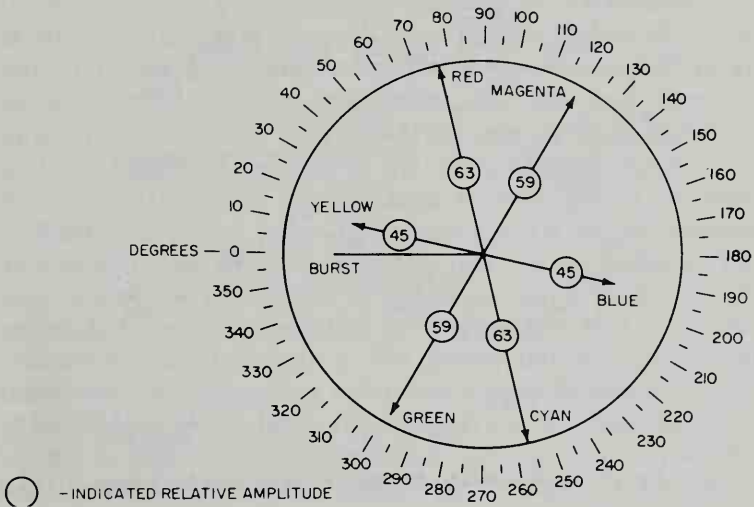
Fig. 30. Vector representation of the relative phases of the TV color signal.

The chief chrominance signals that concern us at this point are R-Y, B-Y, and G-Y, as depicted in Fig. 31. Note that B-Y is 180° from burst. R-Y is 90° from burst. We observe that + (G-Y) is 300° from burst, and that − (G-Y)
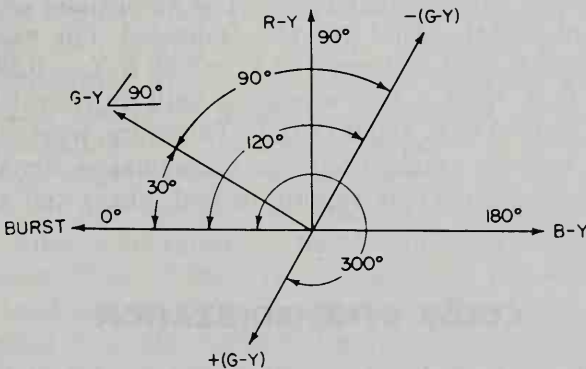
Fig. 31. Phases of G-Y, R-Y, and B-Y signals.

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WHITE	GREEN	YELLOW	RED	MAGENTA	BLUE	CYAN	BLACK
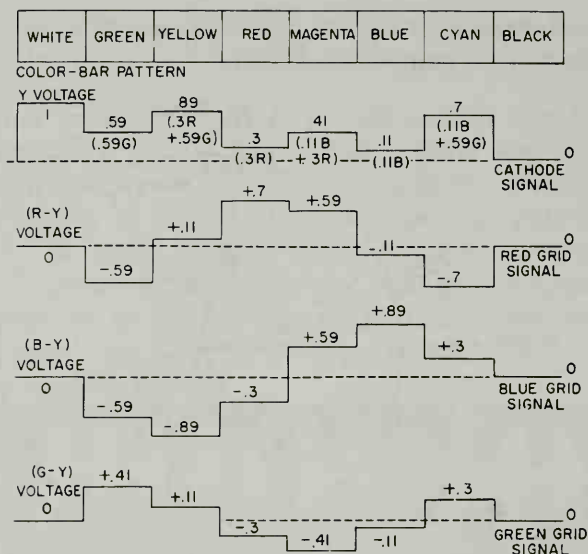
Fig. 32. Signal amplitudes for 100% saturated color bar pattern.

is 180° from + (G-Y). R-Y and B-Y are called quadrature signals, because they are 90° apart. Similarly, G-Y /90° is a quadrature signal with respect to both + (G-Y) and to − (G-Y). These chrominance signals are provided by standard color-bar generators.

Fig. 32 shows how the amplitude of a given chrominance signal varies for different colors. The amplitudes of the Y (black-and-white) signal are also indicated. For example, a green color is built up from 0.59 Y, − 0.59 R-Y, − 0.59 B-Y, and 0.41 G-Y. Next, a yellow color is built up from 0.89 Y, 0.11 R-Y, − 0.89 B-Y, and 0.11 G-Y. Therefore, when a color program is being transmitted, the chrominance signal and the Y signal are varying rapidly in both phase and amplitude.

COLOR SYNCHRONIZATION

In order to reproduce properly the colors of a televised image, the modulation of the chrominance subcarrier at

the transmitter must be reversed at the receiver. It may be recalled that the modulation process at the transmitter involves the use of a 3.58-MHz subcarrier. This subcarrier is applied in quadrature to two doubly balanced modulator circuits. Simultaneously, the saturation signal is applied to one balanced modulator and the hue signal is applied to the other. The 3.58-MHz subcarrier is cancelled, and the resultant output is the chrominance signal. This is a 3.58-MHz signal which varies in amplitude and phase.

Recovery of the color-difference signals in the receiver is accomplished by reversing the modulation process. This requires that a 3.58-MHz CW reference signal that is locally generated should be applied in quadrature to two demodulator circuits. Accuracy in the demodulation process is attained by regulating this reference signal so that a definite phase relationship with the subcarrier is maintained. It is the function of the color-sync section to generate the local 3.58MHz reference signal and regulate its frequency and phase.

A circuit diagram of a typical color-sync, bandpass amplifier, and color-killer section is shown in Fig. 33. This is an example of a ringing-crystal color-sync arrangement. In other words, the quartz crystal is shock-excited into 3.58-MHz oscillation each time that a color burst is applied. Although the ringing waveform tends to die out slightly between bursts, the crystal Q is very high, and the delay is small. Q6 operates as a limiter, to provide a completely uniform output. The quartz crystal is energized by the output from the burst amplifier. In normal operation, the burst-amplifier output waveform appears as shown in Fig. 34. Note that the color killer operates as an electronic switch, to turn the second bandpass stage on or off. The color killer is energized by the output from the subcarrier oscillator. Thus, if there is no color burst present, the second bandpass amplifier is disabled. The burst killer is energized from the horizontal output transformer. It keys out the color burst from the signal in the bandpass amplifier, thereby preventing color contamination in the image from the color burst.

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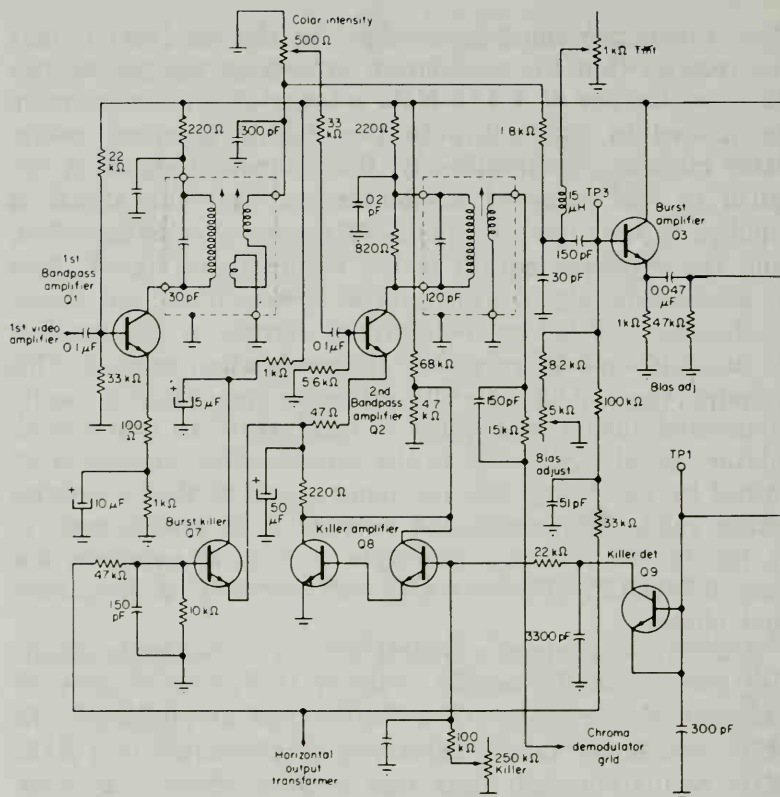
Fig. 33. Configuration of a typical color-sync

COLOR KILLER

The purpose of the color killer in a color receiver is to prevent any signal from getting through the chrominance channel during the time a monochrome signal is being received. This prevents any signal other than the luminance signal from reaching the picture tube. Signals are prevented from passing through the chrominance channel by employing a color-killer stage to bias to cutoff one or more stages in the chrominance channel.
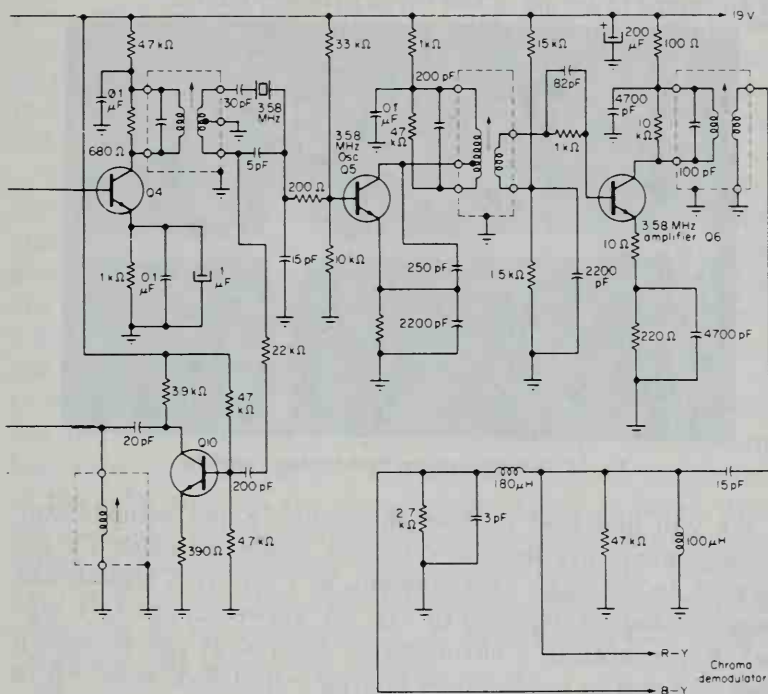
bandpass amplifier and color-killer section.

THE MATRIX AND DEMODULATOR SECTION

At this point in the discussion of color-receiver circuits, three video signals have been described. These are the luminance signal and the two color-difference signals at the output of the chrominance demodulators. It is the function of the matrix section to combine these three signals in the correct proportions so that three color signals are produced. These color signals must correspond to those which appear at the output of the color camera—one for red, one for

green, and one for blue. The color signals are amplified and
applied to the picture tube where they reproduce the hues
of an image in terms of the three primary colors.
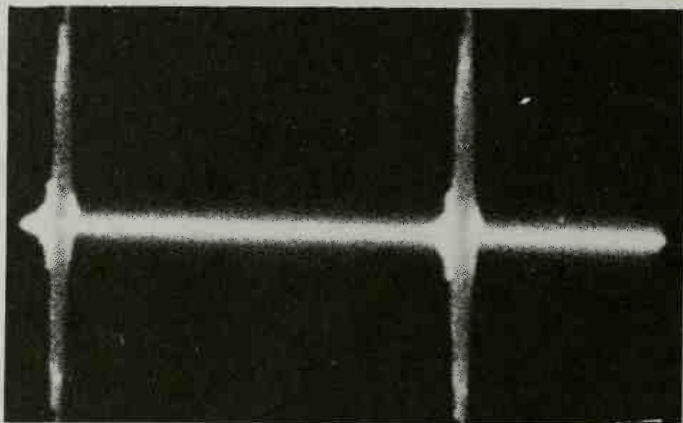
Fig. 34. Output waveform from the burst amplifier.

We will find that various chrominance and demodulator
arrangements are used in different models of color-TV re-
ceivers. In one basic arrangement, R-Y and G-Y signals are
demodulated, as depicted in Fig. 35. However, the G-Y sig-
nal is recovered in a chrominance matrix. It can be shown
that G-Y can be produced by mixing -0.51 R-Y with -0.19
B-Y. An R-Y signal is changed into a $-$ (R-Y) signal by
passing the R-Y signal through a phase inverter. Similarly,
a B-Y signal is changed into a $-$ (B-Y) signal by passing
the B-Y signal through a phase inverter. The G-Y matrix is
simply a mixer for the $-$ (R-Y) and the $-$ (B-Y) signals.
    In order to understand how the colors of a scene are
reproduced, it is necessary to know something about the
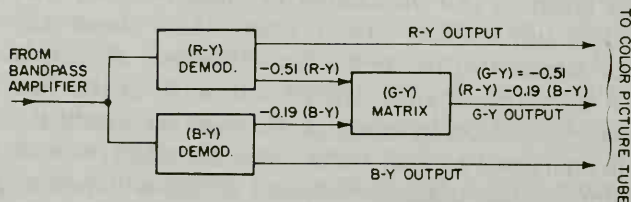
Fig. 35. A basic matrix arrangement.

picture tube. The tube used in the basic color receiver is known as the tricolor picture tube. Three separate electron guns are incorporated in this type of tube in order to accommodate the three color signals. The coating on the face of the tube consists of phosphor dots which are arranged in triangular groups of three. One dot in each trio emits red, one emits green, and one emits blue light.

When operating properly, the electron beam from the red gun activates only the red dots, the beam from the blue gun activates only the blue dots, and the beam from the green gun activates only the green dots. The phosphor dots are closely spaced so that when more than one dot in each trio is activated, the total light emission will blend to form one color. For example, when the light emissions from all three phosphors are equal, the screen appears white. If the red and green phosphors are activated equally, the resultant hue appears to be yellow. The blending into a single hue of the color dots on the picture-tube screen is based upon the principle that the human eye cannot resolve the separate colors at normal viewing distance. As a result, the total light emitted from the dot combinations appears as a single color. Fig. 36 shows how the Y, R-Y, B-Y, and G-Y signals produce a red bar on the screen.

The foregoing information should be helpful in understanding the requirements of the matrix section. A detailed discussion of the picture tube will be presented later.
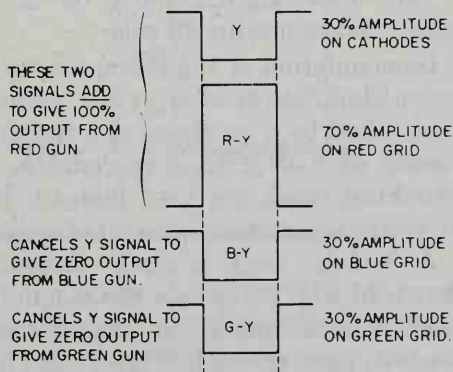
Fig. 36. Waveform amplitudes at the picture tube for a 100% saturated red bar.

In order to produce the colors of an image correctly, the matrix section must fulfill certain requirements. For instance, when a fully saturated red portion of the scene is to be reproduced, the amplitude of the video signal that is applied to the red gun must be at a maximum value and the amplitude of the signals applied to the green and blue guns must be zero. During the time when a fully saturated
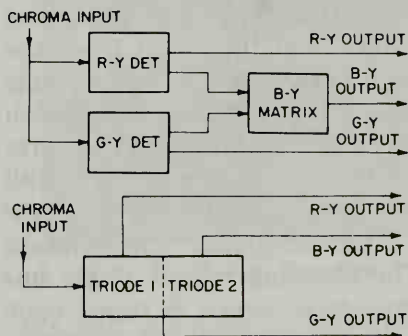
Fig. 37. Common demodulator systems.

green is to be reproduced, the amplitude of the signals applied to the red and blue guns must be zero and that of the signal applied to the green gun must be at maximum value. The amplitude of the blue signal must be at a maximum value and those of the red and green signals must be at zero when a fully saturated blue is being reproduced. If white is to be reproduced, the amplitude of all three of the color signals must be at maximum values, because white contains all colors.

Demodulation of the chrominance signal is the reverse of the modulation process at the transmitter. It could be accomplished by a mechanical switching action; but at a frequency of 3.58-MHz, a mechanical switch is impossible—switching tubes are used instead. Fig. 37 shows the chief chrominance demodulator arrangement.

A widely used chroma demodulator arrangement is shown in Fig. 38. Diode phase-amplitude detectors are utilized. The chroma signal output from the bandpass amplifier is applied to the R-Y, B-Y, and G-Y demodulator diodes.

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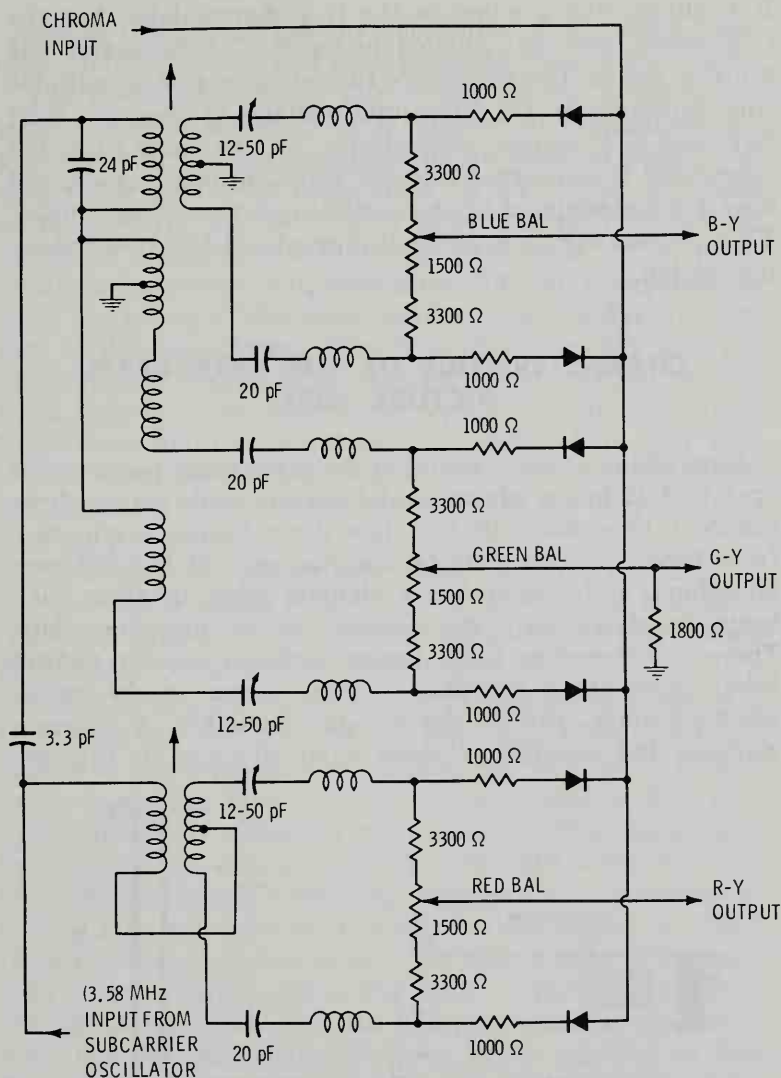
Fig 38. An R-Y/B-Y/G-Y chrome demodulator arrangement.

Also, suitably phased subcarrier voltages from the subcarrier oscillator are applied to the diodes. Thus, the subcarrier voltage applied to the B-Y demodulator has the

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B-Y phase, that applied to the G-Y demodulator has the G-Y phase, and that applied to the R-Y demodulator has the R-Y phase. The diodes are turned on and off at suitable time intervals by the subcarrier voltage to pass the R-Y, B-Y, and G-Y signals, respectively. At the same time, the subcarrier is reinserted into the three chroma signals, and they are demodulated by the rectifying action of the diodes. This process will be explained in greater detail in a following section.

CHARACTERISTICS OF THE THREE-BEAM PICTURE TUBE

Some of the characteristics of the three-beam picture tube are: that it has a phosphor-dot screen made up of three different phosphors, that it has three beams originating from three electron guns to energize each of the different phosphors, and that it has a shadow mask to allow each beam to strike only the correct set of phosphor dots. There are therefore three major parts in a color picture tube. These are a phosphor viewing screen, a shadow or aperture mask, and an electron-gun assembly. A diagram showing the location of these parts appears in Fig. 39.
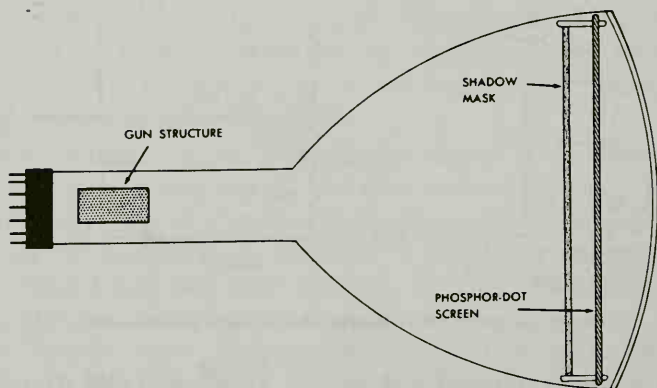
Fig. 39. Drawing showing the locations of the three major parts in the color picture tube.

Let us investigate the characteristics of the three-beam color picture tube by first discussing the three major parts.

The Phosphor Screen—The screen of the monochrome picture tube is made up of a mixture of phosphorescent material which, when energized by an electron beam, will emit white light. This material is placed on the face plate of the tube in the form of a solid screen. The viewing screen of a color picture tube is also made up of phosphorescent material; but, since three different phosphors are used, the screen of the color picture tube is different from that of the monochrome tube. The phosphors are the type that will emit colored light when they are energized by electrons because color has to be reproduced on the screen. Since three additive primaries are employed in color television, three different phosphors are used. The phosphors are deposited on the viewing surface in the form of dots in a set pattern.

These dots are placed very close together, but they do not overlap or touch each other. A third of all the phosphor dots emit red light, another third of them emit green light, and the other third emit blue light.

When an electron beam strikes a red-phosphor dot in a triad, that dot will glow with a red light. When the beam strikes a green-phosphor dot, that dot will glow with a green light. The blue-phosphor dot will glow with a blue light when it is energized with a beam. The characteristics of the human eye are such that the light emissions from the three phosphors cannot be distinguished separately at normal viewing distance. Instead, the eye blends the light from the three sources to give the appearance of a single color. For example, when the light outputs of all three phosphors are equal, each dot will glow with its respective color but the eye blends the three lights together so that the screen will appear to be white. By controlling the energization of the phosphors, it is possible to produce a variety of colors which correspond to the hues in the visible light spectrum. For instance, when only the red and the green phosphors are energized, the two light sources are blended together by the eye and the color yellow is seen. If the

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green and blue phosphors are energized, the eye sees the color cyan.

Shadow or Aperture Mask—It has been stated that the color picture tube has three electron beams. One beam is used for energizing the red-phosphor dots, one for the green-phosphor dots, and the other for the blue-phosphor dots. These three beams must be made to strike their respective set of dots at all times. To make this possible, a shadow mask is placed in the path of the electron beams directly behind the phosphor screen.

The mask consists of a thin sheet of metal that has been etched with a series of very small holes by a photoengraving process. This mask is made large enough to cover the entire phosphor screen. There are as many holes in the mask as there are triads on the phosphor screen—one hole for each dot triad. The placement of the mask in respect to the phosphor dots is shown in Fig. 39. A red, green, and blue dot can be seen through each hole in the mask.

A drawing showing the relationship of the electron beams, the aperture mask and the phosphor-dot screen is presented in Fig. 40. The blue beam is shown as originating
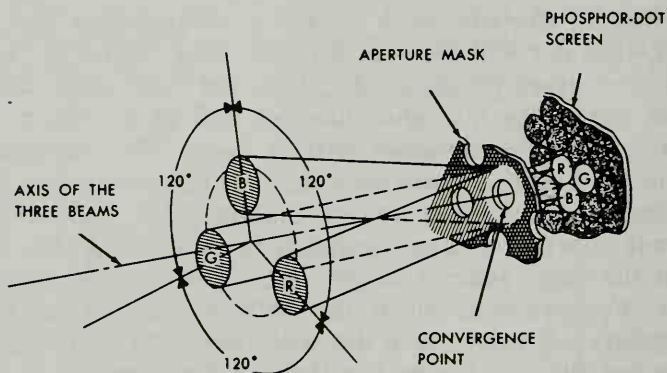
Fig. 40. The relationship between beams. aperture mask, and phosphor screen in the color picture tube.

from the source on the top, the red beam from the source on the lower right, and the green beam from the source on

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the lower left. The three beams are controlled in such a way that they converge and diverge at the same holes in the aperture mask as they are scanned across the screen, and therefore each beam strikes only its respective set of color dots. The blue beam hits the blue-phosphor dot of the particular triad indicated in Fig. 40, and the red and green beams hit their respective dots in this triad. This triad of dots can be likened to the spot produced on a monochrome tube as the electron beam strikes the phosphor screen. Just as the brightness of this spot can be controlled in the monochrome tube by varying the intensity of the beam, the brightness of the triad in the color tube can be changed by controlling the total intensity of the three beams. In addition, however, the beams can be controlled individually; and this makes possible the reproduction of any desired hue.

Electron-Gun Assembly

As was stated previously, the color picture tube employs three electron guns. Each is a complete unit in itself, and all three guns are identical in physical appearance and operation.

Each gun contains a heater, cathode, No. 1 grid, No. 2 grid, No. 3 grid, and No. 4 grid. Grids No. 1 and No. 2 serve the same purpose as they do in a monochrome picture tube, No. 1 being the control grid and No. 2 the accelerating anode. Grid No. 3 in the color tube is the focus electrode. The focus electrodes of the three guns are electrically connected. The high-voltage anode of the color picture tube consists of the inside coating to which the aperture mask and the phosphor are connected.

The three electron beams are aligned so that they are equidistant from each other and from the central axis of the gun structure. In order to obtain this result, each beam is acted upon by a separate beam-positioning magnet which is mounted outside the neck of the tube. By proper adjustment of the three magnets, each beam is positioned with respect to the other two beams.

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With the three beams correctly aligned with respect to each other, the entire system of beams has to be oriented with respect to the central axis of the tube. This is accomplished by a purity coil or magnet which is placed around the neck of the tube and which affects all three beams equally. The adjustment of this control will move all three beams the same amount until they are properly aligned with the central axis of the tube.

The three beams are brought into focus by the action of the No. 3 grids. These grids are electrically connected, which means that all three grids will have the same potential with respect to ground.

After being focused, the beams enter a convergence field which causes them to cross over (converge) at the aperture mask and strike the dots of the correct color. In the latest color tubes, this convergence field is obtained through the use of electromagnets which are mounted around the neck of the tube. During horizontal and vertical deflection of the three beams, they will converge at the center of the screen but not at the edges. To eliminate this condition, dynamic convergence coils are positioned around the neck of the tube. These coils are powered by currents from the horizontal and vertical output stages. The waveforms of these currents are adjustable so that convergence can be obtained over the entire screen.

Another type of color picture tube is called the in-line design, or Trinitron. As shown in Fig. 41, the chief feature of this picture tube is an aperture grille, instead of a· shadow mask. Also, the three electron guns are mounted in line horizontally. Note that all three electron beams pass through the same slot in the grille at a given time, but they pass through at different angles. Therefore, the red beam strikes the red stripe. The same chroma and Y waveforms are used with the aperture grille picture tube as with the shadow mask picture tube. However, the convergence arrangement is quite different. Note that there has been a trend toward the use of elaborated shadow-mask picture tubes that have their deflection yokes and convergence
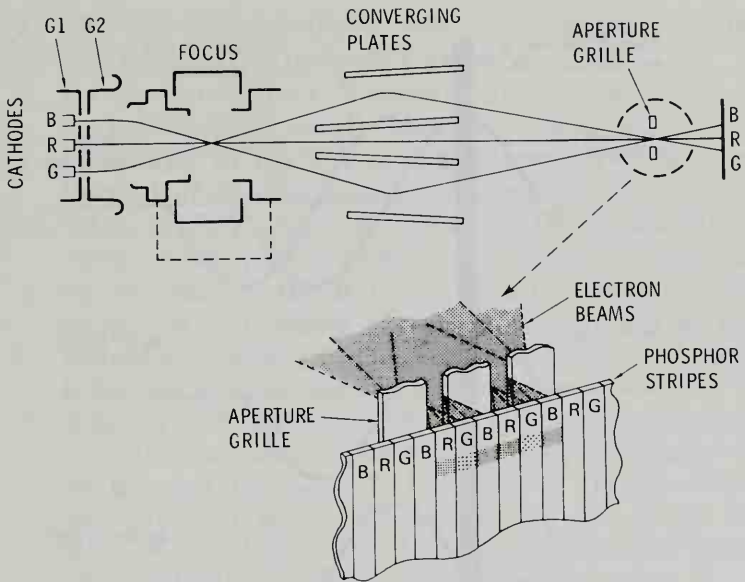
Fig. 41. Constructional plan of an aperture-grille picture tube.

units permanently mounted on the neck of the picture tube. This type of picture tube is converged at the factory, and does not require reconvergence during its useful life. When this type of picture tube is replaced, the york and convergence assembly are discarded with the defective picture tube.

TRANSISTOR COLOR-TV RECEIVERS

Transistor color-TV receivers use various circuits which are essentially the same as previously explained for transistor black-and-white receivers. However, the chroma processing circuits may be basically different from those in tube-type color receivers. Therefore, a typical chroma processing circuit used in a modern transistor color-TV receiver will be explained in this section. It is helpful to start with a brief analysis of chrominance signal demodulation, as depicted in Fig. 42. Note the following facts:

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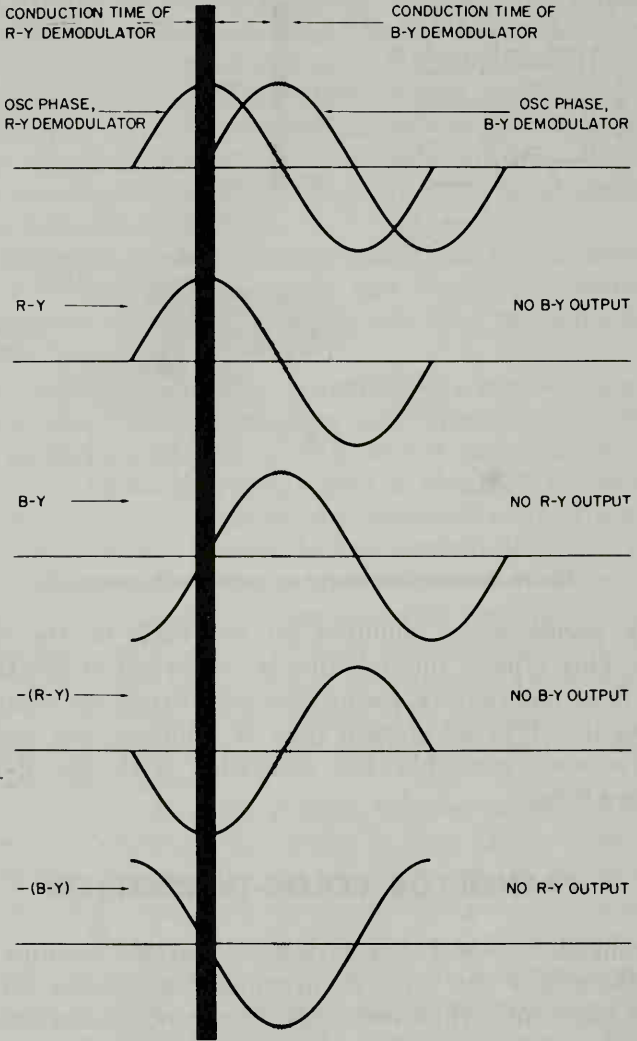
Fig. 42. Sampling the R-Y and B-Y signals.

1. The subcarrier oscillator voltage is injected into the R-Y demodulator in the R-Y phase.

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2. The subcarrier oscillator voltage is injected into the B-Y demodulator in the B-Y phase.
3. Conduction of the R-Y demodulator occurs briefly on the peak of the injected subcarrier voltage.
4. Conduction of the B-Y demodulator occurs briefly on the peak of the injected subcarrier voltage.
5. When an R-Y signal is applied to the demodulators from the bandpass amplifier, the R-Y signal is sampled on its peak by the R-Y demodulator. On the other hand, the R-Y signal is going through zero at the instant of sampling in the B-Y demodulator, and there is zero output from the B-Y demodulator.
6. When a B-Y signal is applied to the demodulators from the bandpass amplifier, the B-Y signal is sampled on its peak by the B-Y demodulator. On the other hand, the B-Y signal is going through zero at the instant of sampling in the R-Y demodulator, and there is zero output from the R-Y demodulator.
7. A minus (R-Y) signal is sampled on its negative peak by the R-Y demodulator and is going through zero at the instant of sampling in the B-Y demodulator. There is a negative R-Y output from the R-Y demodulator, and zero output from the B-Y demodulator.
8. A minus (B-Y) signal is sampled on its negative peak by the B-Y demodulator, and is going through zero at the instant of sampling in the R-Y demodulator. There is a negative B-Y output from the B-Y demodulator, and zero output from the R-Y demodulator.

Next, let us observe the chrominance demodulation arrangement depicted in Fig. 43. Note that the color signal is fed into the color-IF amplifier from the video detector output amplifier. In other words, the color-IF amplifier operates in the same manner as the bandpass amplifiers discussed previously. After the chrominance signal is stepped up through two stages of amplification, it is mixed with the brightness (Y) signal from the contrast control. In other words, the red, blue, and green demodulators are energized
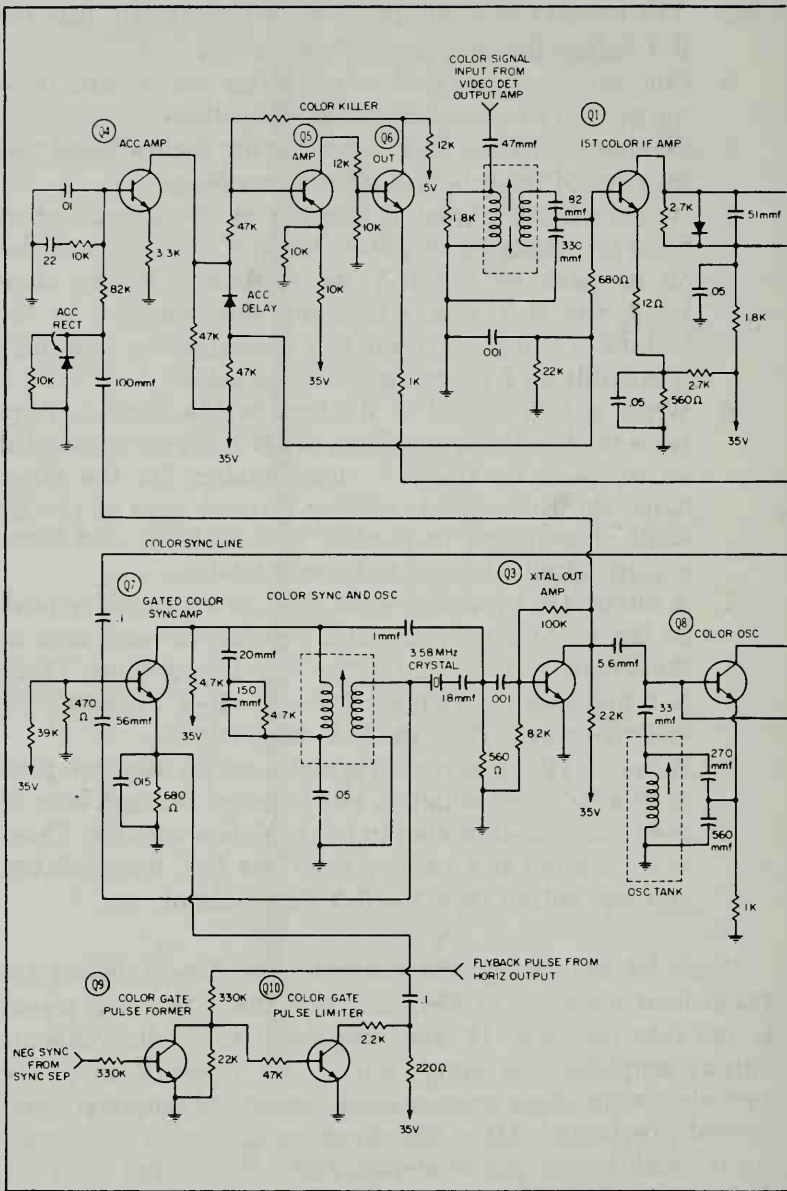
Fig. 43. Typical circuitry
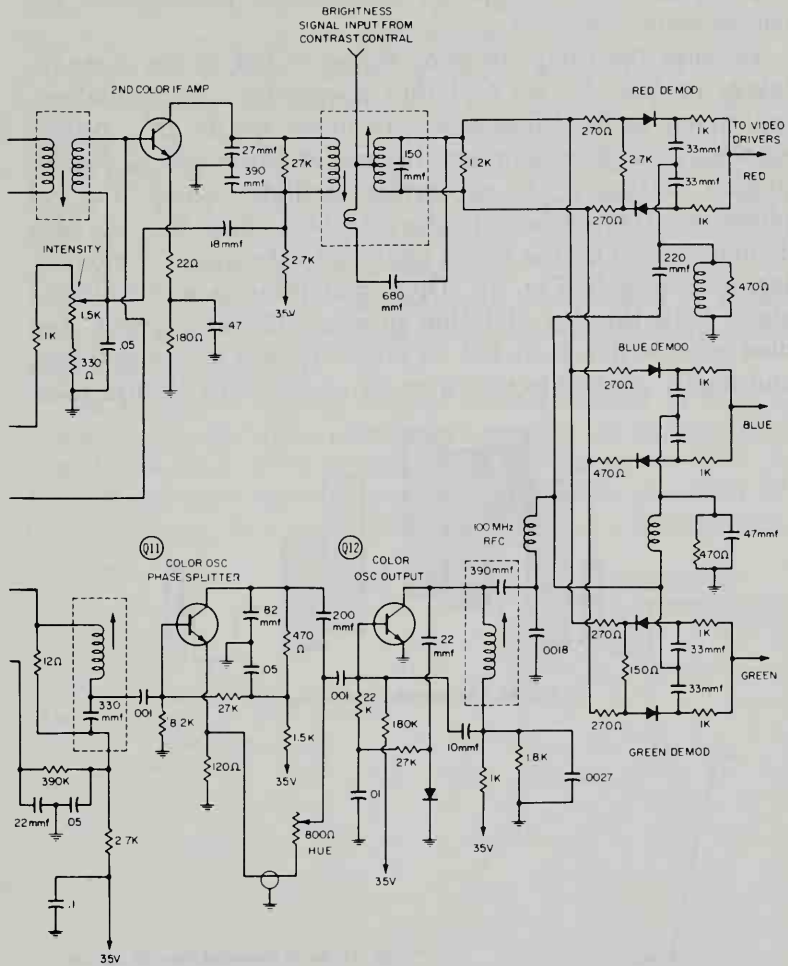
for the color stages.

by the *complete color signal*, as depicted in Fig. 44. This is a basic difference, compared to the other demodulator arrangements described previously.

Because the complete color signal is fed to the demodulators in Fig. 43, we find that a combined demodulation-matrixing action takes place. In other words, this system employs color demodulators, instead of chrominance demodulators. Basically, the subcarrier oscillator injects the red phase into the red demodulator, the blue phase into the blue demodulator, and the green phase into the green demodulator, as shown in Fig. 45. Thus, matrixing is accomplished along with the demodulation process. The red, green, and blue signals are then fed to video drivers and amplifiers, and finally applied to the cathodes of the color picture tube.
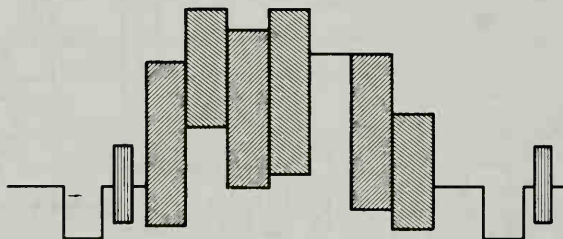
Fig. 44. The complete color signal.
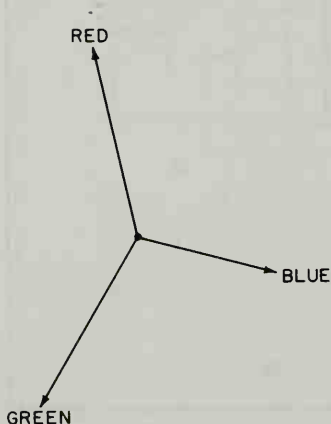
Fig. 45. Basic demodulation phases in the color demodulators.

RGB demodulation entails a problem that is not encountered in conventional chrominance demodulation. That is, spurious pulses called "blips" are produced in a simple RGB demodulation system. Therefore, circuit means must be provided to cancel out the blip interference. This is done by reversing the polarities of the demodulator diodes in the green demodulator section, as seen in Fig. 43. In turn, we would obtain a magenta color-signal output from the green demodulator (Fig. 46), unless the injected subcarrier phase is reversed. Therefore, the subcarrier is injected into the green demodulator in the magenta phase, and a green color-signal output is obtained, due to the fact that the diode polarities are reversed.

The automatic chroma control (ACC) section in Fig. 43 is simply an AGC arrangement to maintain the chrominance signal at a fixed level, in case the incoming signal tends to fade. If the color burst decreases in amplitude, the color-IF gain increases. The color killer operates as explained pre-
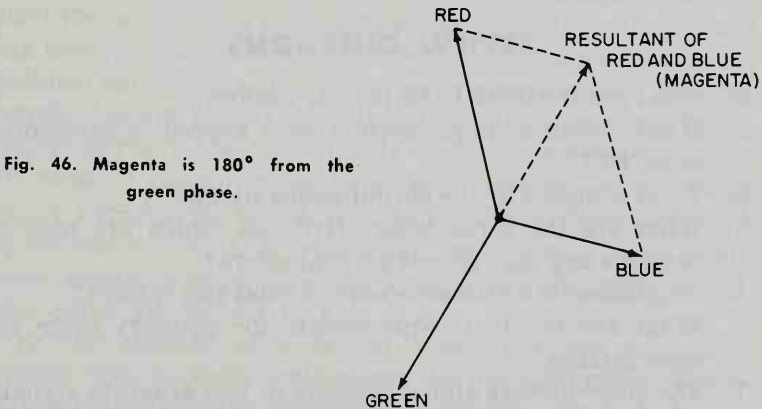
Fig. 46. Magenta is 180° from the green phase.

viously. Similarly, operation of the color-sync and color-oscillator (subcarrier-oscillator) is the same as described previously.

SUMMARY

When color television was first developed, it had to meet two requirements: The color signal had to be compatible

with the monochrome system and be inserted within the 6-MHz channel bandwidth.

There are three color attributes which are used to describe any one color or several colors. These are, hue, saturation, and brightness. Hue is used to identify any color under consideration. Saturation is used to measure the absence of light, and can be expressed as rich deep, vivid, or pure. Brightness defines the amount of light energy which is contained within a given color and can be expressed in terms of bright, dark, or dim.

The color picture signal consists of two separate signals. These are a luminance signal and a chrominance signal. The luminance signal is the portion of the color picture signal utilized by monochrome receivers. The chrominance signal must represent only the colors of a scene, therefore, the luminance signal is subtracted from each of the three output signals of the color camera.

REVIEW QUESTIONS

1. What are the three basic primary colors?
2. What two basic requirements were needed in developing color TV?
3. What is meant by the chrominance signal?
4. What are the three color attributes which are used to describe any one color or several colors?
5. Brightness is a characteristic of what two factors?
6. What are the two requirements for primary color for color mixing?
7. The color picture signal consists of two separate signals. What are the two signals?

Television Alignment

Although each receiver is correctly adjusted at the fac-
tory, rough handling during transit and aging components
may cause misalignment of the critical circuits. If picture
and sound defects indicate that a realignment is necessary,
the manufacturers' step - by - step procedure should be
followed.

In order to better understand the following detailed align-
ment procedure, it is necessary to explain why this procedure
has been prepared in this manner. Any receiver alignment
problem may be classified either as *minor* or *major*. In other
words, it is either only slightly out of adjustment and there-
fore requires minor adjustments of one or more of the coils;
or, some of the coil cores have been removed, or are badly
out of adjustment, which will necessitate a thorough check
of the entire circuit. A preliminary overview of basic align-
ment setups is shown in Fig. 1. Typical coils with adjust-
able cores are shown in Fig. 2.

In the absence of a screen room, external noise and
signals may be very troublesome during alignment. There-
fore a stage-by-stage procedure is usually followed, during
which the signal is injected just preceding the stage under
alignment. If it is known that the set is not badly out of
alignment, it may be possible and practical to abbreviate
the procedure considerably by applying the input signal
directly to the antenna input during the entire alignment
procedure, instead of applying it to the different tubes as
each individual stage is aligned.

(A) An RF tuner alignment setup.

(C) A chroma

Fig. 1. TV alignment

SWEEP/MARKER GENERATOR

RF OUT

SWEEP VOLTAGE

ADJUST VERT SIZE OF DISPLAY

AC

ADJUST HORIZ SIZE OF DISPLAY

EXT

VIDEO DETECTOR

DIRECT

MIXER

RF TUNER

OSC

I-F AMPS

AGC BIAS

VIDEO AMPS

(B) An IF alignment setup.

ADJUST VERT SIZE OF DISPLAY

ADJUST HORI SIZE OF DISPLAY

AC

EXT

DEMODULATOR PROBE

VIDEO AMP

FIRST COLOR AMP

SECOND COLOR AMP (BANDPASS AMP)

DEMOD

alignment setup.

RECEIVER

BIAS

COLOR KILLER

Courtesy B&K Precision, Div. of Dynoscan Corp.

setup.

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Fig. 2. Coils with adjustable cores.

One important point should be kept in mind when making all adjustments. That is to align all the individual coils at the same frequency setting of the generator rather than changing the generator setting and having to go back and try to reset the generator at the same frequency. For example, when making adjustments at 41.25 MHz do not change the generator setting from the time of starting these adjustments until all adjustments on all coils that are to be aligned at this particular frequency have been completed even though this means changing the point of signal injection. The exact frequency to which the coils are aligned is not as important as it is to be sure that all coils of identical frequency are aligned at exactly the same frequency. The frequency tolerance of $\pm$ 5% in signal generator frequency can be tolerated if the coils are aligned at the identical frequencies.

Again it should be emphasized that all pertinent data relating to the set to be aligned should be available for reference and the manufacturer's alignment procedure must be followed.

General Alignment Procedure—To align a television receiver, or any other receiver or device employing wide-band circuits, a visual indication of the response of the circuit

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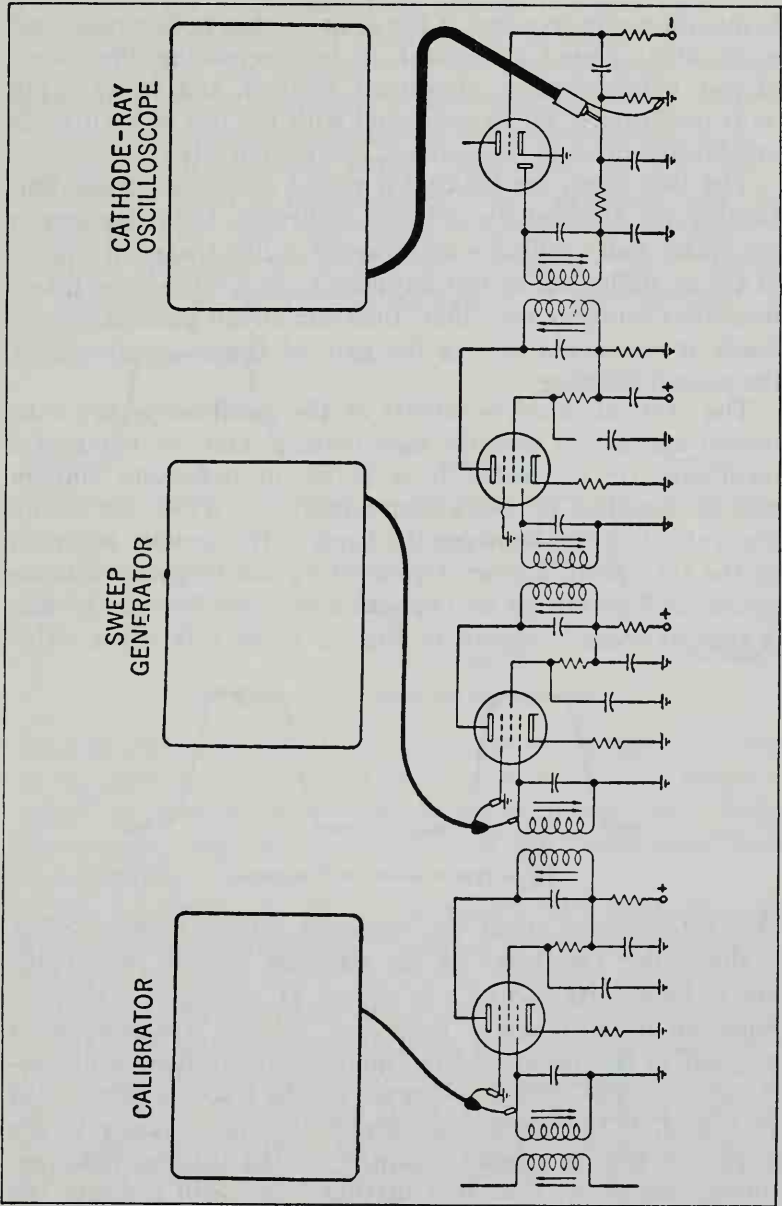
Fig. 3. Typical visual-alignment setup.

being aligned is required if the alignment is to be considered acceptable. Visual alignment is fast replacing the older, slower point-by-point alignment method and is as rapid as it is effective. When combined with the use of accurately established marker frequencies, it is also precise.

The test setup for making a visual alignment when employing the aforementioned test calibrator, television sweep generator and a suitable oscilloscope is illustrated in Fig. 3. If the amplifier under test happens to be a wide-band intermediate-frequency amplifier, then the sweep generator normally is connected first to the grid of the stage preceding the second detector.

The vertical input terminals of the oscilloscope are connected across the detector load resistor and the horizontal terminals are connected to a source of deflection voltage usually supplied by the sweep generator. When the sweep generator is tuned to sweep the band of frequencies accepted by the IF circuit, a trace representing the response characteristics of the circuit will appear on the oscilloscope screen. A typical trace is shown in Fig. 4. From this trace, valu-

Fig. 4. Typical tuned-circuit response.

able information about the response can be obtained; but if the center frequency of the response and its bandwidth are to be determined to any degree of accuracy, a marker must be used. When a source of marker frequencies is coupled to the input of the amplifier under test, a discontinuity, or "pip" will be observed on the trace, as illustrated in Fig. 4. If the marker generator is tuned exactly to the center of the pass band accepted by the intermediate-frequency amplifier, then this marker "pip" will indicate the position of that frequency on the trace. Knowing the center

frequency, the serviceman then adjusts the final tuned circuit for a trace that is of maximum amplitude, and is symmetrical about the marker "pip" or has the shape recommended by the manufacturer of the equipment being aligned.

Preceding stages are then adjusted progressively by moving the sweep generator output cable back, stage by stage toward the input of the amplifier while adjusting, stage by stage, the individual interstage coupling transformers.

Fig. 5 illustrates the position of the marker "pip" relative to the response for various conditions of misalignment. It

(A) Response correct but frequency low.

(B) Frequency correct but response not symmetrical.

(C) Response correct but frequency high.
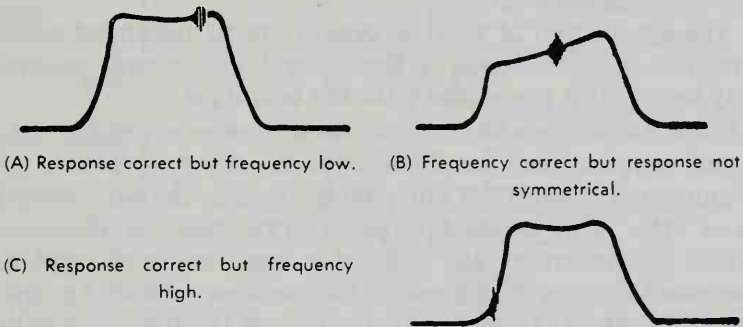
Fig. 5. Response of improperly aligned circuits.

must be emphasized that once the marker generator is tuned to the correct frequency, it is the position of the response which is incorrect and which must be moved over under the marker "pip" by adjustments of the tuned circuits in the amplifier.

The determination of the bandwidth of a particular response is another important function of marker generators. Fig. 6 shows how this is performed. After the amplifier is aligned, the marker generator is tuned to a lower frequency, so that the marker "pip" falls on the 70% response point on the low-frequency side of the response curve. The frequency at this point is read from the marker-generator dial scale, then the generator is tuned toward a higher frequency until the marker "pip" rests on the high-frequency side of the curve at the 70% response point. This frequency is also read from the dial scale. The difference between the two
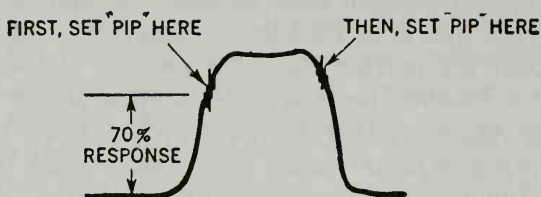
Fig. 6. Bandwidth measurement.

frequencies is equal to the bandwidth of the amplifier at the 70% response points.

The application of marker generators to alignment problems has been discussed in the foregoing in a very general way to acquaint the reader with the technique.

Since various models of television receivers employ different coupling and amplifier circuits, any one method of alignment, if described completely in this chapter, would be of little value to the television serviceman. In all cases, before alignment of any television receiver is attempted, the *manufacturer's alignment instructions should be consulted.* However, since the application of the television calibrator to alignment techniques is in all cases simply and clearly indicated, its use can be described in sufficient detail to cover all methods of alignment. Accordingly, the following applications will proceed with the assumption that the other equipment required is set up and operated in conformance with the *manufacturer's instructions* pertaining to the *particular receiver* under test, and according to standard visual alignment technique.

Aligning Video IF Amplifier—The test equipment and the receiver are set up as shown in Fig. 7. When the sweep generator is tuned to sweep the passband of the Video IF amplifier, a trace similar to that of Fig. 8 should appear on the oscilloscope screen. This trace is typical of the video IF response of modern television receivers. Since the intermediate frequencies for most television receivers are 45.75 MHz for picture and 41.25 MHz for sound, these frequencies are shown in their proper position in Fig. 8.
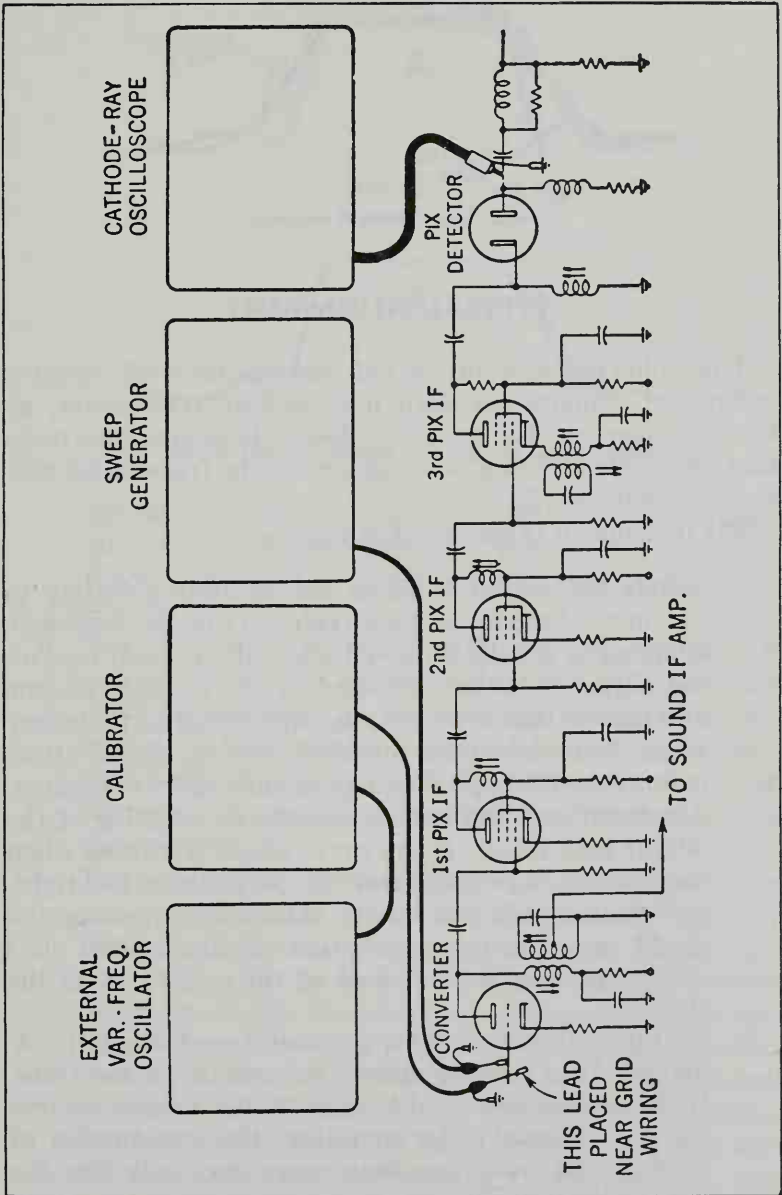
Fig. 7. Test equipment and receiver setup in alignment of video IF amplifier.

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Fig. 8. Typical video IF response.

TYPICAL ALIGNMENT

The following description will assume that the receiver under test employs standard intermediate frequencies, although under no circumstances does this assumption mean that receivers utilizing other intermediate frequencies cannot be aligned easily.

The instrument is employed as follows:

1. Couple the output cable of the calibrator loosely to the input of the mixer tube (refer to Fig. 6). Sufficient coupling is usually obtained when the ground lead on the output cable is connected to the receiver chassis and the *hot* lead is placed near the wiring of the mixer stage. Some television receivers, having comparatively low gain IF amplifiers may require tighter coupling. Too much coupling is undersirable, as detuning of the circuit may result. If the curve shape is altered when the marker signal is inserted, coupling is too tight. Sufficient coupling is easily obtained by pulling the shield over the mixer tube out of the ground clips and connecting the *hot* lead of the calibrator to the shield.
2. Set the calibrator frequency exactly on 45.75 MHz. A marker "pip" should appear somewhere on the trace. If the oscilloscope used to observe the response curve has a wide-band video amplifier, the combination of marker "pip" and response curve may look like the curve shown in Fig. 9A. A sharper marker "pip" may be obtained when the high-frequency response of the
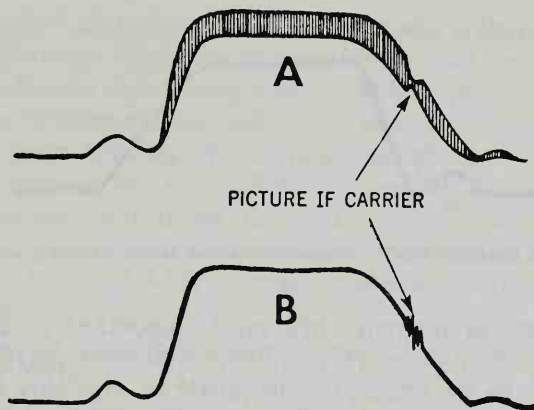
Fig. 9. Trace of video IF response as it might be seen on oscilloscope.

oscilloscope vertical amplifier is decreased by shunting the vertical input terminals with a small capacitor (about .001 MFD). The resulting trace is shown in Fig. 9A.

3. The position of the 45.75 MHz marker (picture IF carrier) should be approximately the 50% response point on the slope of the response curve, as shown in Fig. 9. The tuned circuits in the picture IF amplifier are adjusted so that the response curve is of the proper shape with the marker "pip" in the position shown in Fig. 9.

4. The position of any frequency in the response curve can be determined by placing the marker "pip" at that point and reading the frequency from the tuning-dial scale. One important frequency is that where the response just starts to drop off toward the sound-carrier frequency (see Fig. 10). If the variable-frequency oscillator of the calibrator is set and calibrated to the picture IF carrier and the external variable-frequency oscillator is set to a frequency which is the difference between the picture IF carrier and the frequency whose marker "pip" is shown in Fig. 10, two simultaneous markers will appear.

SOUND IF CARRIER
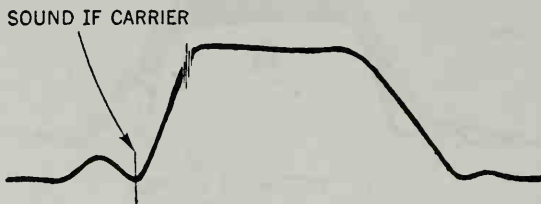
Fig. 10. Trace of video IF response with sound carrier frequency marked.

These frequencies are most important in the alignment of picture IF amplifiers and their marker "pips" may be kept in sight constantly to eliminate the necessity of retuning and recalibrating the signal source. Other important frequencies are the trap frequencies shown in Fig. 11.

Since the response of the amplifier is very low at the trap frequencies, the marker "pip" will disappear when it is placed on these frequencies; however, these points can be determined on the response curve by placing the marker "pip" first on one side of the trap frequency, then on the other, and interpolating the center frequency. During preliminary alignment when the response of the amplifier at

ADJACENT CHANNEL
PICTURE IF CARRIER

ADJACENT CHANNEL
SOUND IF CARRIER

ACCOMPANYING
SOUND
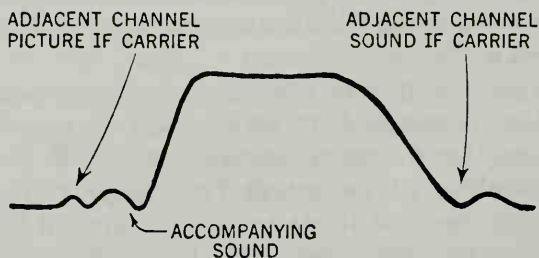
Fig. 11. Trace showing typical trap frequencies.

the trap frequencies has not been tuned to a minimum, a marker can be placed on the adjacent channel sound IF carrier or adjacent channel picture IF carrier. These markers can be obtained from a separate variable frequency oscil-

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lator tuned to 1,500 kHz and connected to the "MOD IN" jack of the calibrator. With the variable-frequency oscillator of the calibrator set for a main marker at the sound or picture IF carrier frequency, markers will appear 1.5MHz away from the main marker. Two simultaneous marker "pips" may be provided by the calibrator, one at the sound IF carrier and the other at the picture IF carrier when the output of the variable-frequency oscillator is tuned to either frequency and the 4.5-MHz crystal oscillator output is used to modulate it.

This may be accomplished by turning the calibrate selector to 4.5 MHz. It is advisable to maintain the RF OUT control near its maximum clockwise position whenever internal modulation is employed. If the marker amplitude is still too high, it may be reduced by looser coupling to the amplifier input point. The size of the marker "pip" can be increased by turning the RF OUT control clockwise, or by coupling the output cable closer to the amplifier under test, or both. Coupling which is too tight, however, may result in detuning of the IF amplifier and consequent distortion of the response.

Traps in the picture IF amplifier are adjusted by feeding the output of the television calibrator, tuned to the trap frequency, into the IF amplifier. Each trap is adjusted for minimum output as indicated by a sensitive vacuum tube voltmeter connected across the second detector load resistor. If the output of television calibrator is modulated by the internal audio signal, an oscilloscope or a highly sensitive vacuum tube voltmeter may be used as an output indicator.

The general procedure in aligning picture IF amplifiers is first to set the traps and then to align the other circuits in the IF amplifier. Since any adjustment made on these other circuits will in most cases slightly detune the traps, they may have to be "touched up" during the picture IF amplifier alignment. The manufacturer's alignment instructions will again determine the exact procedure to follow.

Alignment RF Amplifiers—The radio-frequency stages of a television receiver should have a passband of about 6 MHz (see Fig. 12). The equipment for producing this is set up

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and operated according to the manufacturer's alignment in-
structions and the output of the calibrator is fed into the re-
ceiver antenna terminals. Normally, the calibrator is tuned
to the center frequency of the channel being aligned, then
the tuning adjustments in the RF amplifier are adjusted
to produce a response which is symmetrical on each side of
the marker "pip".

The output frequency of the calibrator is tuned to either
the picture or sound carriers. When either of these fre-
quencies is correctly marked on the RF response curve as
seen on the oscilloscope, a marker "pip" appears at the
other part of the curve if the output frequency is modulated
by 4.5 MHz. To do this, the calibrate selector is set at the
4.5 MHz position and two "pips," one marking the sound
carrier and the other marking the picture carrier, are
seen on the response curve and are spaced exactly 4.5 MHz
apart.

Aligning RF Oscillators—The local oscillator in the tele-
vision receiver can be rapidly and efficiently aligned by
feeding the sound-carrier frequency into the input of the
receiver and adjusting the receiver oscillator to obtain zero
output from the sound discriminator. This procedure can
be followed only after the sound IF system has been cor-
rectly aligned. The procedure for a receiver using a dis-
criminator is as follows:

Fig. 12. Trace of typical RF response.

1. Couple the output of the calibrator to the input of
   the receiver.
2. Connect a zero-center voltmeter to the output of the
   sound discriminator (across the discriminator load-re-
   sistors).

3. Set the calibrator to 215.75 MHz (channel 13 sound).
4. If the receiver has a fine tuning control, this should be set at the center of its tuning range.
5. Adjust the channel 13 oscillator trimmer for zero output from the discriminator. Check this point by turning the trimmer through the correct setting. The discriminator output should be positive on one side of the proper adjustment and negative on the other.
6. Adjust the remaining channels in a similar manner. In each case set the calibrator to the appropriate sound-carrier frequency. Since the order of alignment may differ in receivers of different make, the manufacturer's instructions should be consulted before proceeding.
7. If the receiver uses a ratio detector, a VTVM can be connected across the stabilizing capacitor and the oscillator trimmers tuned for a maximum VTVM reading.

Aligning Sound IF Amplifiers—With the exception of the response-curve shape, the application of the calibrator to alignment of sound IF channels follow the same general procedure given in the previous paragraphs on picture IF channels. The alignment equipment is set up as shown in Fig. 13. The IF response, with the superimposed marker "pip" is shown in Fig. 14 as being indicative of that to be expected from normal sound IF amplifiers.

The width of the passband can be determined as described previously under *"General Alignment Procedure."* The usual discriminator characteristic is shown in Fig. 15A. Fig. 15B shows the usual discriminator response curve with the center frequency (sound IF) modulated by a .25 MHz frequency. Three simultaneous markers are provided by modulating the center frequency with the .25-MHz frequency. These marker "pips" are 250 kHz apart and are used to check discriminator bandwidth.

The center marker "pip" may not be visible since it is at a point of zero voltage and, consequently, the two visible

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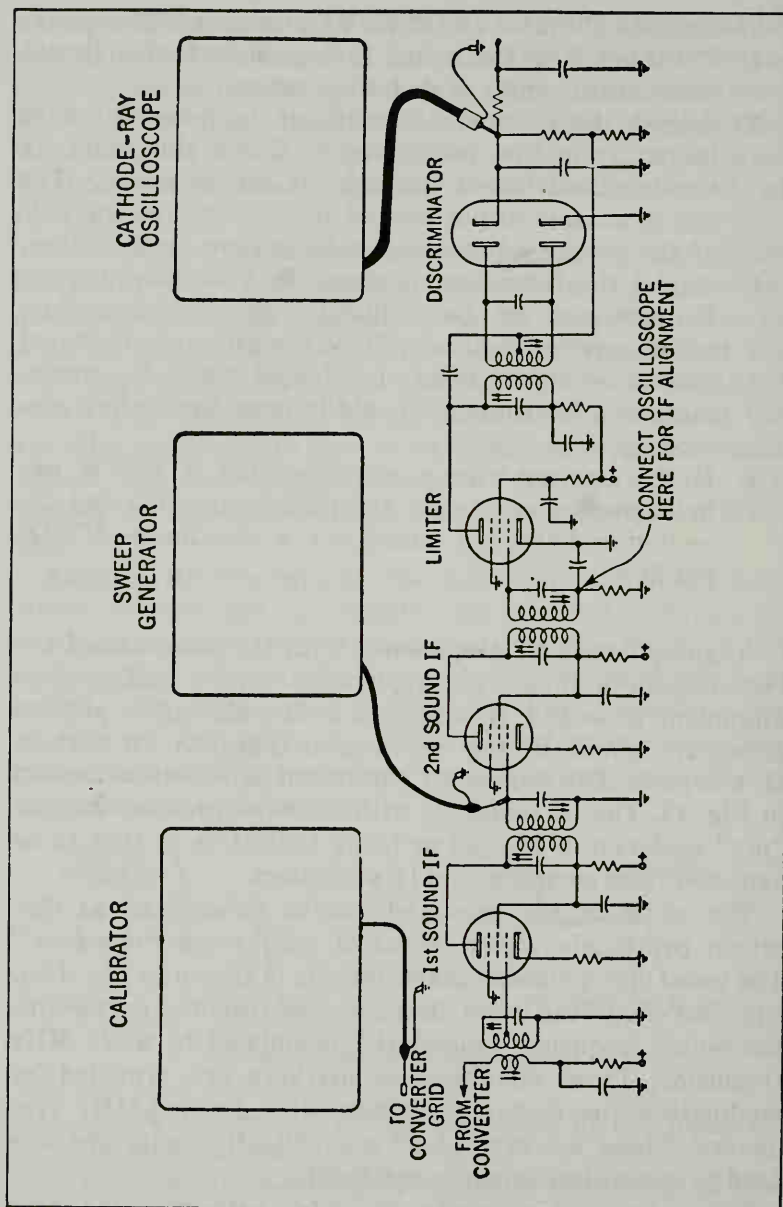
Fig. 13. Typical setup for sound IF amplifier alignment.

Fig. 14. Trace of sound IF response.

CENTER
FREQUENCY

250
KHz

A

B

P ←—500KHz—→ P

C

Fig. 15. Typical discriminator response.

(A) With capacitor across oscillator
input.

(B) Without capacitor.
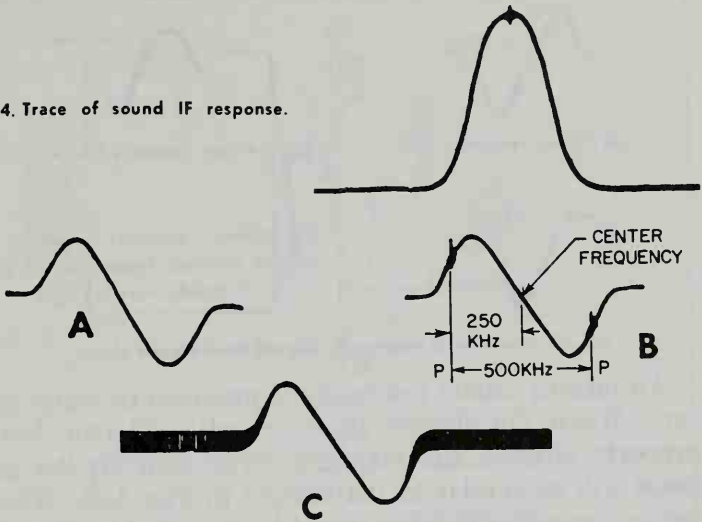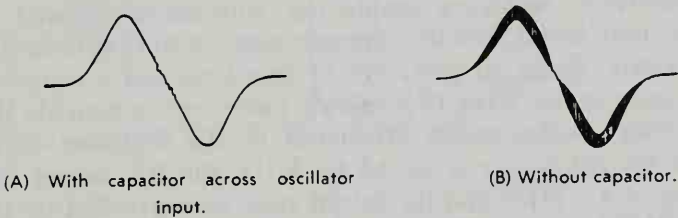
Fig. 16. Typical discriminator response.

"pips" will be 500 kHz apart. If the small capacitor previously shunted across the oscilloscope vertical input is removed, a trace like that of Fig. 16B will appear. Using this trace, the serviceman can determine the important center frequency of the discriminator characteristic with relative ease. Fig. 17 illustrates the various conditions of discriminator misalignment.

Another method of aligning the discriminator or ratio detector of television receivers is to obtain the usual response such as that shown in Fig. 15A. The center frequency (sound IF) is then modulated by an audio frequency.

(A) Correct response.

(B) Secondary resonant frequency high.

(C) Primary resonant frequency too high or resonant frequencies of other IF transformers too high.
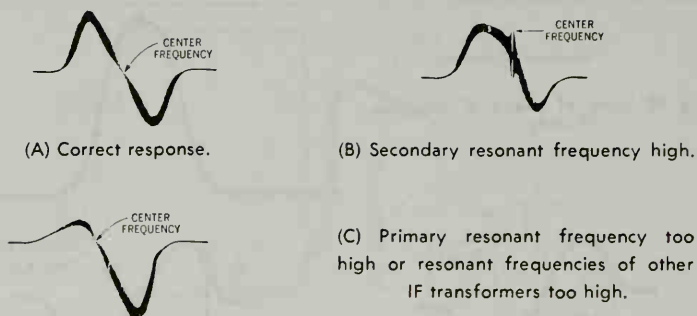
Fig. 17. Response of improperly aligned discriminator circuit.

An internal audio frequency is provided in many generators. When the discriminator or ratio detector has been properly aligned, the response curve seen on the oscilloscope will be similar to that shown in Fig. 15A. When the center frequency is other than that provided by the generator, the response curve will be similar to that in Fig. 15C.

Television receivers employing intercarrier sound IF stages may be aligned in a manner similar to that described previously. Since all receivers of this kind use a sound IF frequency of 4.5 MHz, it is merely necessary to provide this frequency as the center frequency of the response curve. When the calibrator is set to 4.5 MHz, the RF output frequency is 4.5 MHz and its output may be controlled by the RF "OUT" control. This output is fed into the video amplified ahead of the 4.5 MHz take-off point. If additional markers are needed they can be obtained by connecting the output of an ordinary variable-frequency oscillator to the "MOD IN" jack of the calibrator.

Second-Detector and Video-Amplifier Response Check— This test portrays on the screen of an oscilloscope a trace which shows the response of not only the video amplifier in a television receiver, but of the second detector and its load as well. Equipment for the test is set up according to Fig. 18. The method follows:

1. Connect the outputs of the television calibrator and the sweep generator directly to the diode element not connected to the diode load. See Fig. 18.
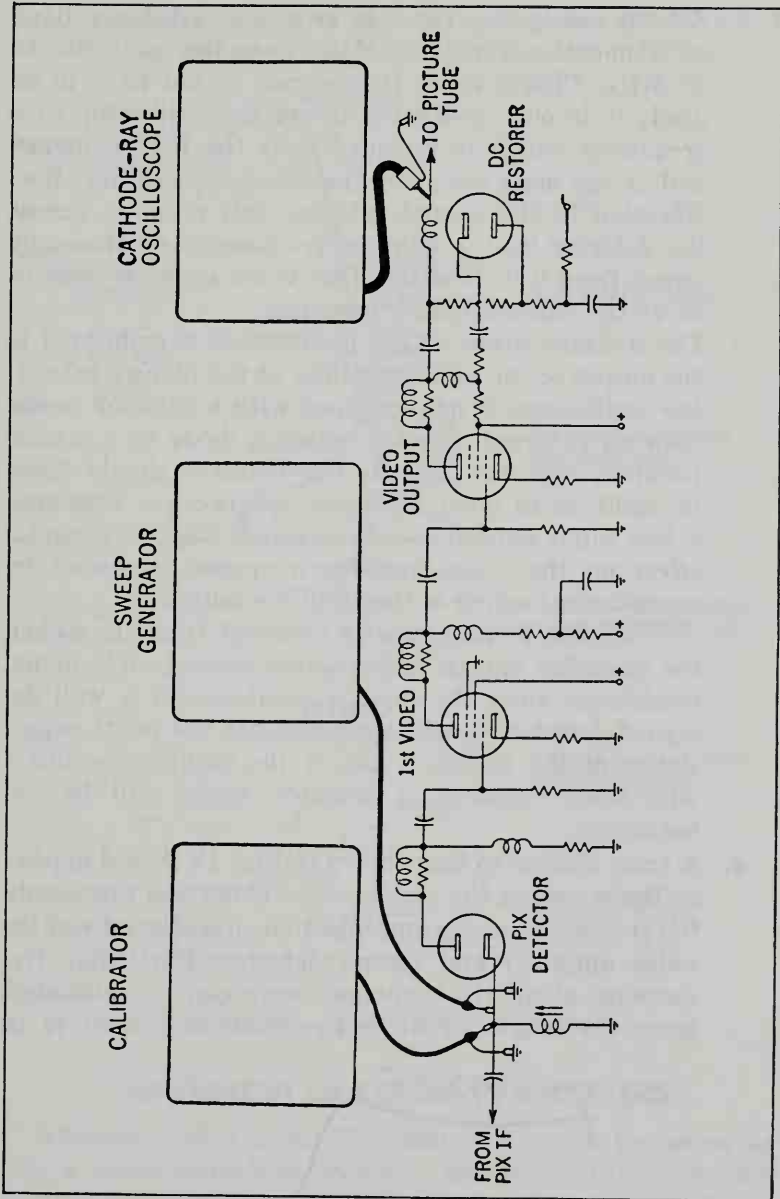
Fig. 18. Typical setup for second detector and video amplifier response check.

2. Set the sweep generator to sweep an arbitrary band of frequencies, say 20-30 MHz. Tune the calibrator to 20 MHz. (These exact frequencies do not have to be used; it is only necessary to set the calibrator to a frequency which is included near the low-frequency end of the band swept by the sweep generator). Rectification in the second detector will produce, across the detector load, a band of frequencies continuously swept from 0 to 10 MHz. This video sweep is used to check the video-amplifier response.

3. The detector probe of the oscilloscope is connected to the output of the video amplifier at the picture tube. If the oscilloscope is not equipped with a detector probe, then an external detector, using a diode or a crystal rectifier, may be utilized. The detector should have, in addition to good 60-Hertz square-wave response, a low input capacitance to preclude any detrimental effect on the video-amplifier response produced by capacitance loading of the amplifier output.

   When the picture tube is removed from its socket, the amplifier can be tested under more nearly actual conditions, since the input capacitance of a well designed detector closely approximates the input capacitance of the picture tube. If the oscilloscope has a wide-band response, a detector probe will be unnecessary.

4. A tract similar to that shown in Fig. 19 should appear on the screen of the oscilloscope. This trace represents the frequency versus amplification characteristic of the video amplifier and second detector. Particular frequencies along the response curve can be estimated, since the length of the entire trace is known to be
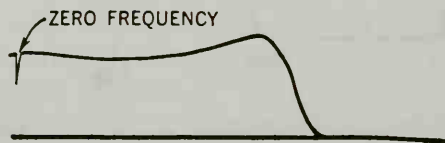
Fig. 19. Video amplifier and detector response.

representative of a video-frequency bandwidth equal to the sweep-width output of the sweep generator.
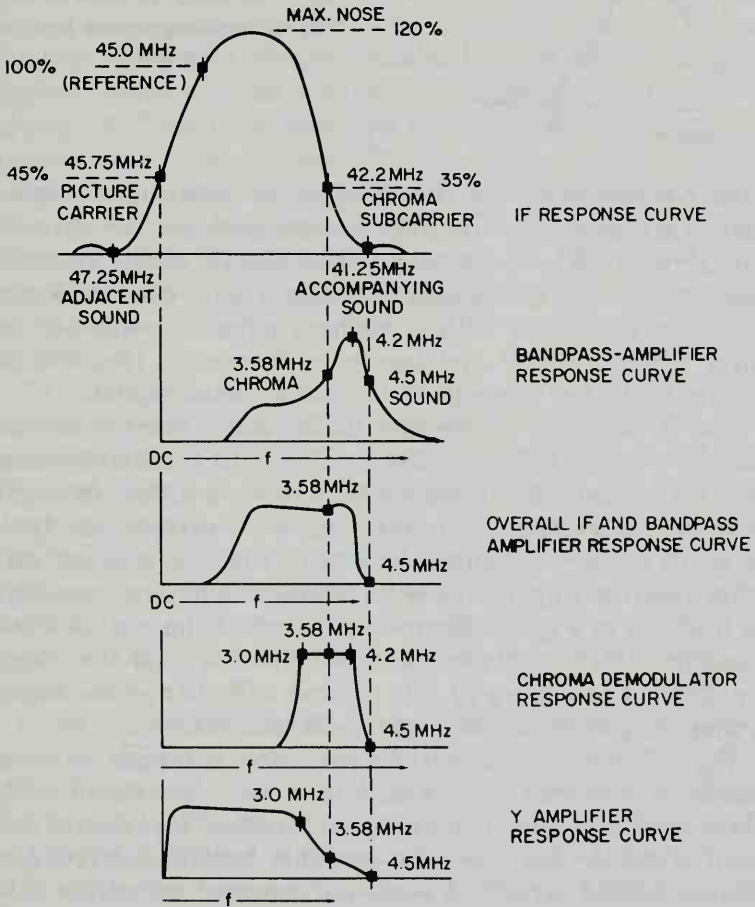
Fig. 20. Response of the video-signal channels.

ALIGNMENT OF COLOR-TV RECEIVERS

Alignment of a color-TV receiver is much the same as for a black-and-white receiver, except that the chroma section presents somewhat different requirements. With reference to Fig. 20, it is helpful to observe the relative fre-

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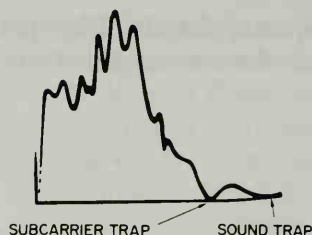
Fig. 21. Frequency-response curve for Y amplifier.

SUBCARRIER TRAP   SOUND TRAP

quency-response curves for the various video-signal chan-
nels of a typical color receiver. In this example, the chroma
subcarrier falls at the 35% point on the IF curve. To com-
pensate for chroma-sideband attenuation, the bandpass
amplifier is aligned with a rising frequency response. In
turn, the overall IF and bandpass frequency response is
substantially flat through the chroma-signal region.

The Y amplifier is checked in the same manner as ex-
plained previously for a video amplifier in a black-and-white
receiver. Y-amplifier response curves have different speci-
fications for various color receivers. For example, one type
of curve for a Y amplifier is seen in Fig. 20, whereas an-
other receiver employs more extensive subcarriers trapping,
as depicted in Fig. 21. Some color receivers have a picture-
peaking control between the video detector and the video
amplifier. The setting of this control will change the high-
frequency portion of the response considerably.

Fig. 22 shows a circuit diagram for a typical chroma
bandpass amplifier and a bandpass response curve with
absorption markers. The sweep-and-marker signals are ap-
plied at the grid of the video-amplifier tube that drives the
chroma-takeoff circuit. A scope is connected across the out-
put load of the bandpass amplifier (color-saturation control
in Fig. 22). Either a low-capacitance probe or a demodula-
tor probe can be used with scope; the frequency-response
curve illustrated in Fig. 22A is an envelope display obtained
with a demodulator probe. A circuit for a demodulator
probe (sometimes called a traveling detector) is shown in
Fig. 24.

Absorption markers may be provided in the video-fre-

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quency sweep generator, or an external marker-absorption box may be used. The appearance of an absorption-marker box is seen in Fig. 25. The video-frequency sweep signal is passed through the marker box before it is applied to the receiver under test. Traps contained in the box (Fig. 26) produce notches in the frequency-response curve as shown in Fig. 27. This is an envelope response, produced when a demodulator probe is used with the scope. If a low-capacitance probe is used with the scope, a video-frequency pattern appears as depicted in Fig. 28. To the frequency of a marker "notch," the operator touches his finger to a terminal button in Fig. 25. In turn, body capacitance causes the associated notch to become more shallow and to move on the pattern.

To summarize an important point, corresponding unde-modulated and demodulated video-frequency response patterns are shown in Fig. 29. The undemodulated pattern is obtained with a low-capacitance probe, while the demodulated response is obtained with a demodualtor probe. The envelope of the response patterns is the same. If a narrow-band scope is used, a demodulator probe is necessary to avoid pattern distortion. On the other hand, if a 4-MHz scope is used, a low-capacitance probe may be employed if desired.

If the example of Fig. 22, three slug adjustments are provided to align the bandpass section. We observe that the curve illustrated in Fig. 22A has greater bandwidth than that shown in Fig. 23. It is necessary to consult the service data for the particular receiver to determine the optimum bandwidth. The override bias voltages that are required for alignment procedures are also specified in the receiver service data. For example, an override bias voltage must usually be applied to the color-killer circuit in order to pass a sweep signal through the bandpass amplifier. The color-killer bias voltage in Fig. 30 is fed to both the bandpass amplifier tube and the secondary of the oscillator transformer L28. This secondary winding connects to the chroma demodulator tubes in the following receiver section. Thus,

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the killer bias cuts off both the bandpass amplifier and the chroma demodulators.

The burst amplifier has a narrow bandwidth. In other words, L26 in Fig. 30 is sharply tuned, with a peak frequency of 3.58 MHz. To align this stage, we simply use an unmodulated 3.58-MHz signal from a signal (or marker) generator and adjust slug A17 for maximum output, as indicated by a scope or a VTVM. It is advisable to use a crystal-calibrated marker generator because the alignment of the burst amplifier is somewhat critical.

Fig. 30 also shows the chroma reference oscillator and control sections. Coils L27 and L28 have narrow-band response, and a color-bar generator is generally used for alignment. We proceed by disabling the burst-amplifier tube, so that the subcarrier oscillator is free-running. If pin 1 of V18 is shorted to ground, the flyback gating pulse cannot drive the tube into conduction, and the circuit is disabled. A VTVM may be connected to pin 2 of V19 to indicate the amplitude of the subcarrier oscillator signal. If no DC voltage is measured, the subcarrier oscillator is not operating; in such case, slug A8 is turned as required to start the oscillator. Next, slug A16 is adjusted for maximum VTVM reading. This completes the first portion of the alignment procedure.
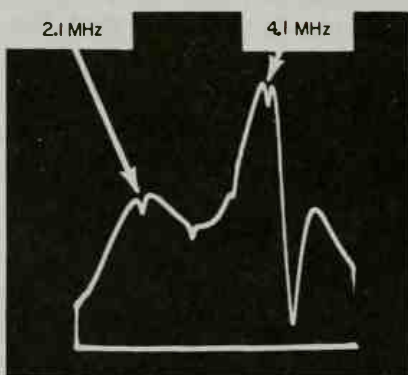
(A) Bandpass response curve with rising high-frequency response.

Fig. 22. Circuit diagram of a
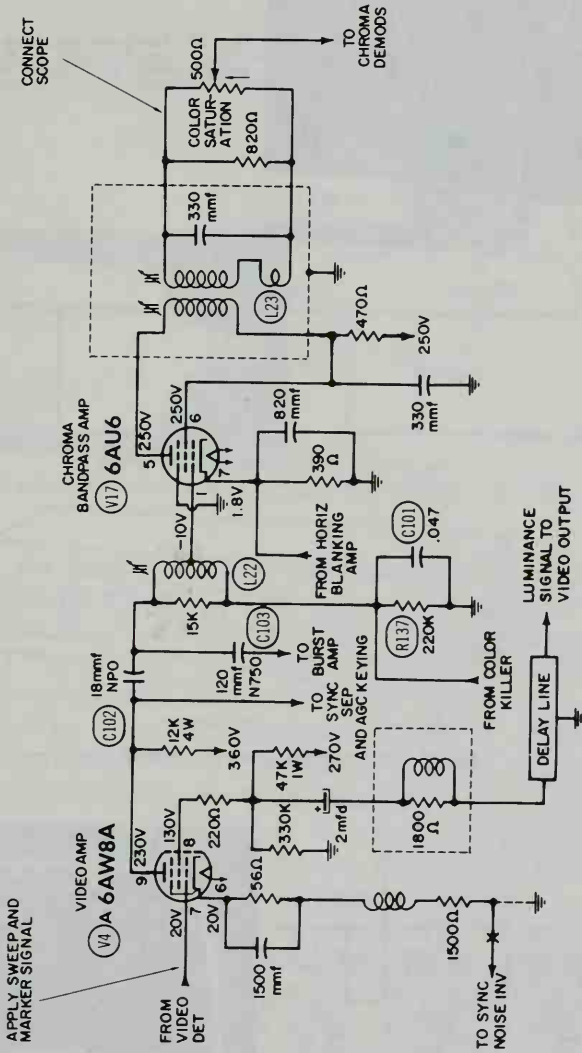
(B) Schematic diagram.

typical bandpass amplifier.

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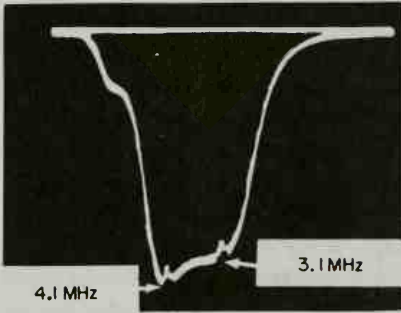
Fig. 23. Bandpass response curve with comparatively little high-frequency rise.
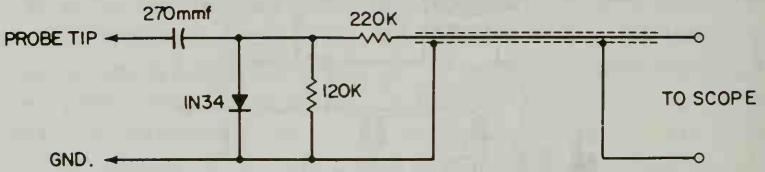
Fig. 24. Circuit for a demodulator probe.
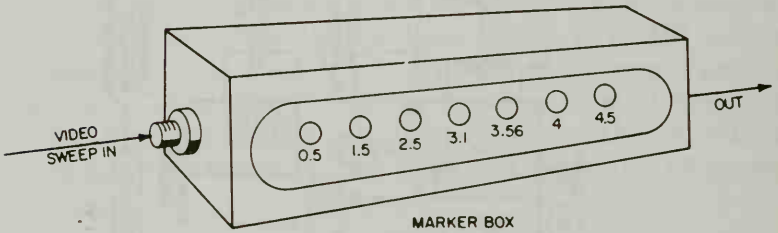
Fig. 25. Physical appearance of a marker box.
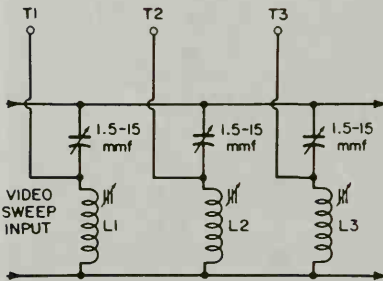
Fig. 26. Circuit configuration of a marker box for three markers.
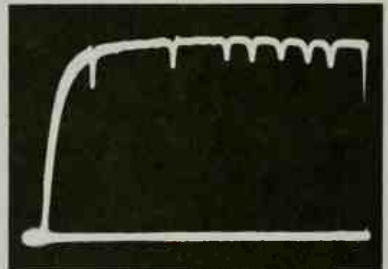
Fig. 27. Marker demodulated video curve.

Fig. 28. A video-frequency pattern obtained with a low-capacitance probe.

1.5MHz
.5MHz
3.0MHz
3.58MHz
4.1MHz
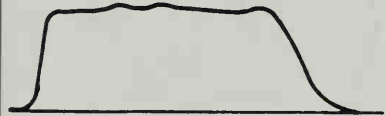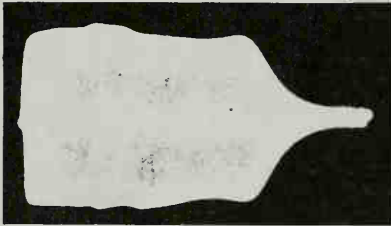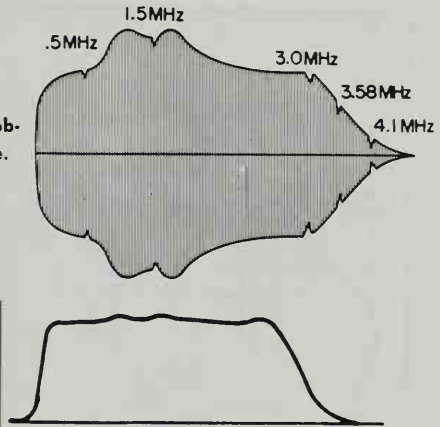
Fig. 29. Corresponding undemodulated and demodulated frequency-response patterns.

Next, we remove the short from grid to ground in the burst-amplifier circuit. If slug A17 has not been previously adjusted, it may be turned at this time to provide a maximum VTVM reading. That is, L26 is aligned to resonance with the color-burst signal from the color-bar generator. Thus far, the subcarrier oscillator is only in rough alignment; in other words, the oscillator may be "pulling" appreciably against the reactance tube in Fig. 30. This is undesirable, because the receiver will tend to lose color sync on weak incoming signals. Hence, we proceed to make a touch-up adjustment of the subcarrier oscillator.

In this final step, we can connect the VTVM to test point O in Fig. 30. It is very likely that either a positive or a negative voltage will be indicated. We adjust slug A18 to obtain a zero-volt indication on the VTVM. A cross-check can be made by reducing the output from the color-bar generator to a very low level. The color-bar display on the picture-tube screen should remain in sync. If the color bars break up into "rainbows" at a low signal level, the foregoing alignment procedure should be repeated. After the sub-
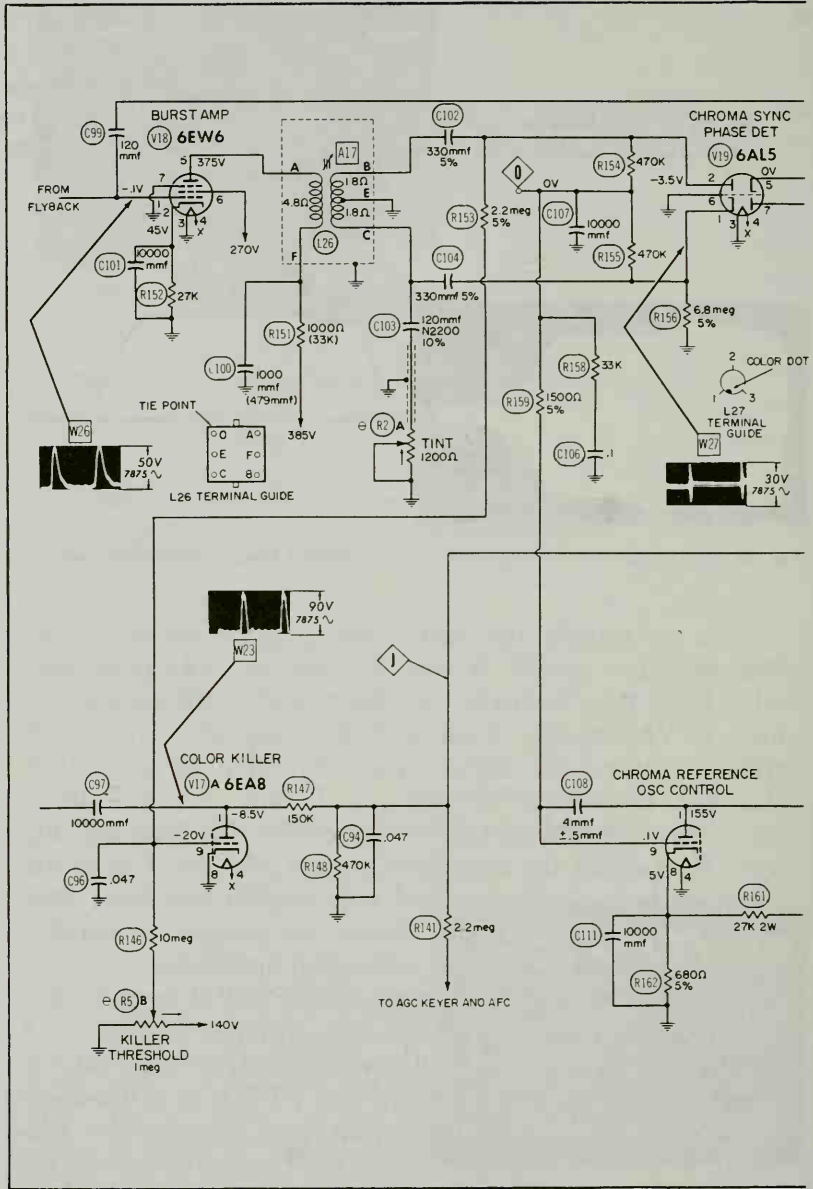
Fig. 30. The bandpass amplifier may
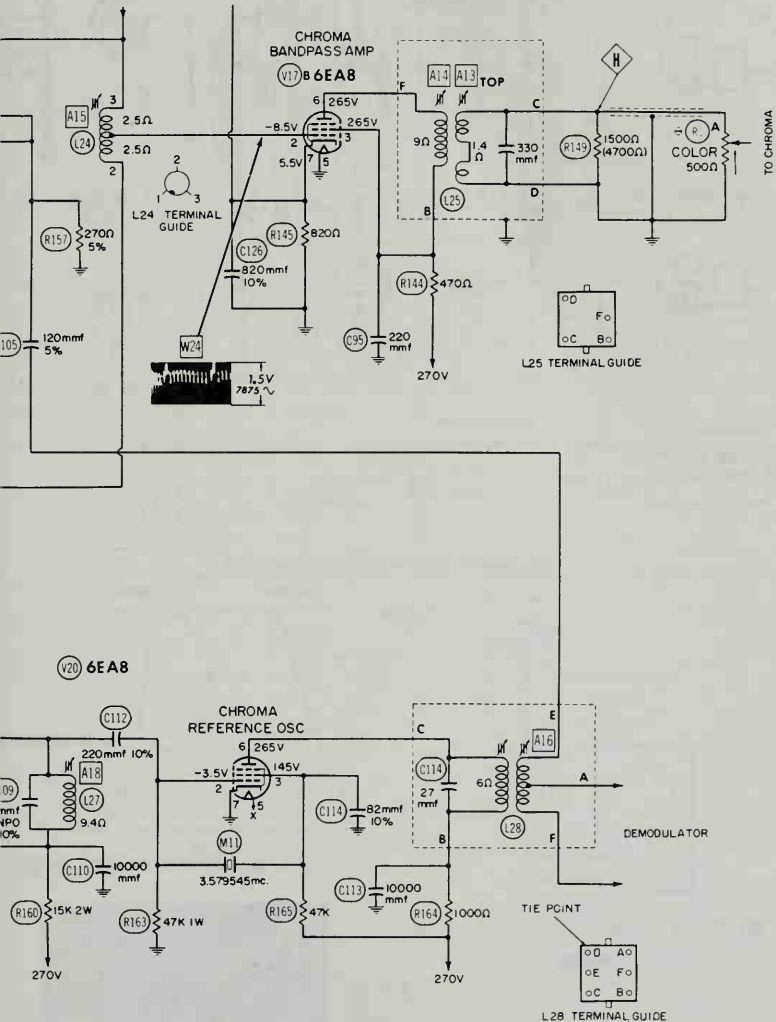
be cut off by the color killer.

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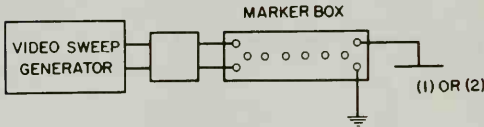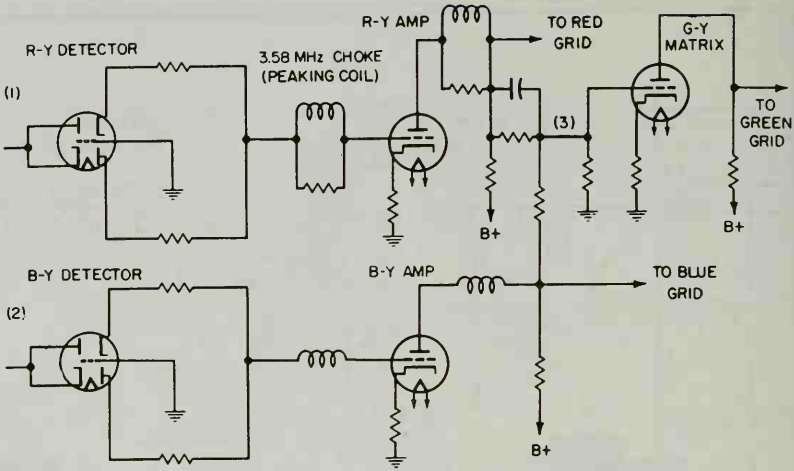
(A) Sweep and marker signal applied.
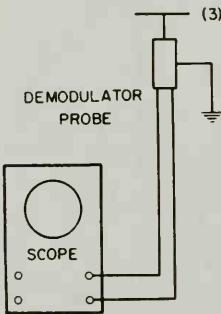
(B) Scope connected at demodulator output.
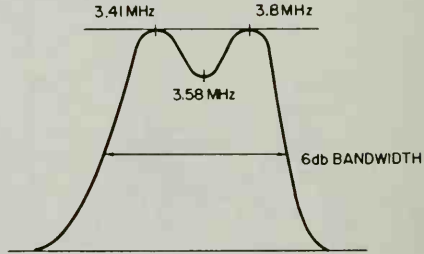
(C) Typical demodulator response curve.

(D) Display of a demodulator response curve on oscilloscope screen.
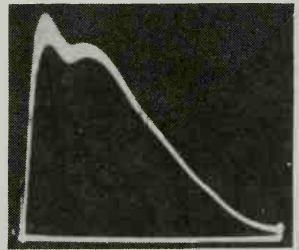
Fig. 31. Basic chroma-demodulator configuration.
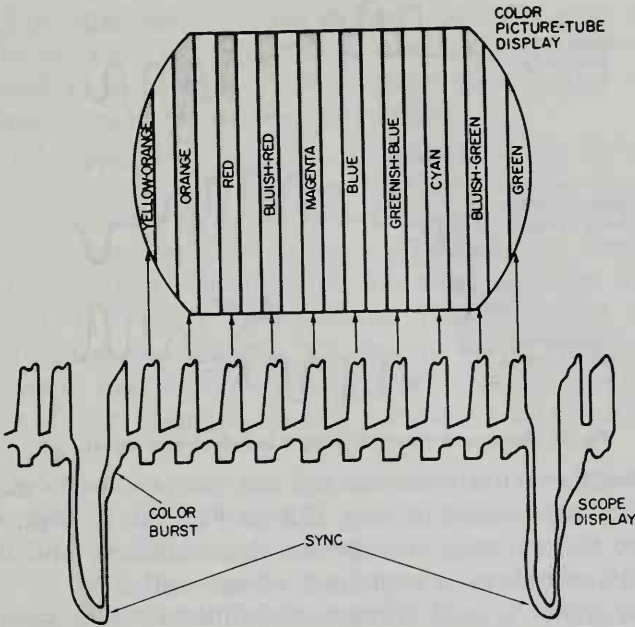
(A) Keyed-rainbow signal and hues corresponding to each bar.
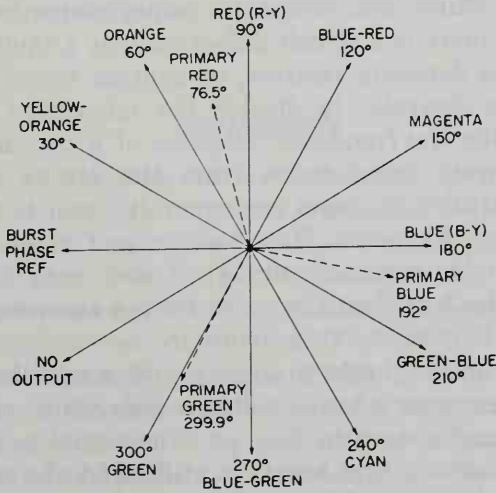
(B) Phase progression of a rainbow signal.

Fig. 32. Setup for checking chroma demodulators with a keyed-rainbow generator.
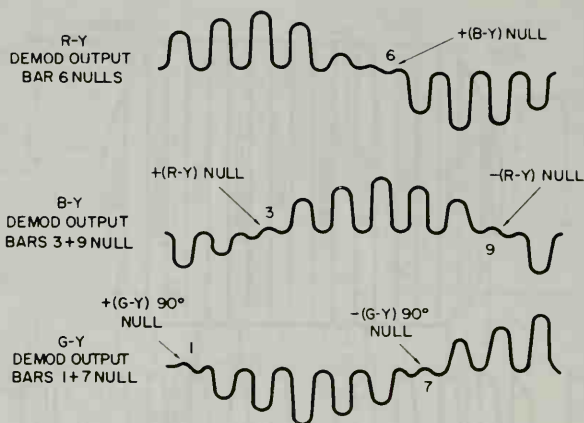
Fig. 33. Demodulator outputs using a keyed-rainbow signal.

carrier oscillator has been checked out, we proceed to make a touch-up adjustment of slug 17A in Fig. 30, if required. However, this involves the chroma demodulators, and this alignment procedure is explained subsequently.

Fig. 31 shows a basic chroma-demodulator configuration. This is a simple arrangement in which the inductors are fixed-tuned. Therefore, if the frequency-response curve is not normal, there is a circuit defect such as a faulty capacitor, off-value damping resistor, or shorted turns in an inductor. It is desirable to disable the subcarrier oscillator when checking the frequency response of a chroma demodulator, to avoid interference from the strong 3.58-MHz signal. Absorption markers are generally used to check the bandwidth of the curve. Manufacturers of color receivers may not provide specified curves; in such case, it may be possible to check against the curve from a receiver which is known to be in good working condition.

Phase-alignment checks are made with a color-bar generator. Most shops use a keyed-rainbow generator, which provides the signal shown in Fig. 32. The signal contains 11 bursts, of which the first bursts is utilized by the color sync section. The following 10 burst produce color bars on the picture-tube screen as shown in the diagram. Each burst advances in phase by 30° from the previous burst, as shown

in Fig. 32B. The color-bar signal is usually applied to the antenna-input terminals of the receiver, and a scope is connected at the output of the chroma demodulator which is being checked for phase alignment.

Note that phase-alignment checks apply to chroma matrixes, as well as to chroma demodulators. In other words, if we are checking a G-Y signal channel, it makes no difference whether the G-Y signal is produced by a demodulator or by a matrix. The color picture tube is always driven by R-Y, B-Y, and G-Y signals. If the phase alignment is correct in these three channels, we observe scope patterns as depicted in Fig. 33. We count bars, or "pips" to check the null points. For example, an R-Y output signal should null on bar No. 6.

Occasionally, tuning slugs are provided for adjustment of the phases of the injected subcarrier signals. Often, the circuits are fixed-tuned. As noted in the discussion of frequency response curves, an incorrect pattern indicates a defective component such as a faulty capacitor. That is, if one or more of the nulls in Fig. 33 occur at incorrect bars, we proceed to check the components in the associated circuit.

SUMMARY

A stage-by-stage procedure is usually followed during alignment due to external noise which can be very troublesome. It should also be kept in mind that all pertinent data relating to the particular set to be aligned should be available for reference and the manufacturer's alignment procedure must be followed.

The vertical input terminals of the oscilloscope are connected across the detector load resistor and the horizontal terminals are connected to a source of deflection voltage usually supplied by the sweep generator. When the generator is tuned to sweep the band of frequencies accepted by the IF circuit, a trace representing the response characteristics of the circuit will appear on the scope screen. The

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marker is used to obtain valuable information as to response and degree of accuracy.

The position of the picture IF carrier (45.75 MHz) should be at approximately the 50% response point on the slope of the response curve. If the marker generator is tuned exactly to the center of the passband accepted by the IF amplifier, then this marker will indicate the position of that frequency. Knowing the center frequency, the service-man then adjusts the final tuned circuit for a trace which is of maximum amplitude.

REVIEW QUESTIONS

1. Why is the signal injected just preceding the stage under alignment?
2. How many Hertz is the sound and video IF separated?
3. Why should markers on response curve be observed?
4. What is the response point? What percentage?
5. What is the picture IF (in megahertz) in most TV receivers? Sound IF?

Television Test Equipment

In the alignment and troubleshooting of a television receiver, a number of factors must be considered. The test equipment employed should be suitable for this type of work. All pertinent data relating to the television receiver to be aligned, should be available for reference and the manufacturer's alignment procedure must be followed closely.

Test Equipment Required—At the outset it should be pointed out that no set of rules as to the number and exact specifications of the instruments required can be given here. Rather an effort will be made to give the most common type of equipment necessary in the average practice, and also to explain how these equipments are used to accomplish their assigned function. (See Table 1).

The intelligent servicing of a television receiver requires, first, a knowledge of the operation of the receiver and second, a knowledge of the normal waveforms to be expected in the circuits of the particular equipment.

The pieces of test equipment necessary for alignment and effective troubleshooting and usually found in the average television service shop are as follows :

1. Oscilloscope.
2. Sweep generator.
3. Signal generator.
4. Vacuum tube voltmeter.

Table 1. Test methods for troubleshooting TV receivers.

		Secondary Tests	
Section	**Primary Tests**	**1**	**2**
Power supply	VOM or VTVM	Scope	— — — — — —
Audio	Signal injection	VOM or VTVM	Scope
Video amplifier	Scope	VOM or VTVM	Listening test or signal injection
Vert. deflection	Scope	VOM or VTVM	6.3 VAC signal injection
Horiz. Deflection	Scope	VOM or VTVM	Sawtooth signal injection
Horiz. AFC-OSC	Scope	VOM or VTVM	— — — — — —
Video IF	VTVM	Signal tracing or injection	Aligment check
AGC	"Clamping" with bias supply	Scope	VTVM
RF tuner	VTVM	Signal injection	Aligment check
Sync	Scope	VOM or VTVM	— — — — — —
Sound IF and FM detector	Signal injection	VOM or VTVM	Aligment check

5. Miscellaneous test equipment.

The Oscilloscope—Few instruments are of greater utility in television receiver testing than is the oscilloscope. A cathode-ray oscilloscope is necessary when alignment is performed with a sweep oscillator. It can also be employed with a modulated signal generator to align wave traps and other narrow-band circuits. It is also used in the sync and sweep circuits of the television receiver to observe the fidelity of the various waveforms and to ascertain their presence at various points. The amplifiers, particularly the vertical amplifier, determine the utility of any particular oscilloscope in television receiver testing. A typical oscilloscope is illustrated in Fig. 1.

The best criterion of satisfactory operation is the faithful reproduction of a square pulse at a repetition rate of from 100 to 15,000 Hertz per second. Defined in terms of frequency response, which does not take into account

Courtesy Heath Co.

Fig. 1. The Heath 10-102 oscilloscope.

phase discrepancies, this is, roughly, uniform response from 30 to 150,000 Hertz.

The synchronizing of the oscilloscope to that of the wave-form being observed is accomplished through a switching arrangement, from two or three possible sources; external, internal or 60 Hertz. Each switch position connects the sweep generator in the oscilloscope to the respective sources. The external position allows injection of sync

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through a binding post on the front of the instrument. This allows any pulse (whether actually derived from the trace under observation or not) of the correct frequency to synchronize the trace. It is thereby possible, through the use of a phase-shifting network, to vary the portion of the pattern at which the trace begins and so change its position on the screen. A 60-Hertz sync is usually internationally provided because a larger portion of the traces encountered are some multiple or submultiple of this frequency.

Internally, the signal synchronizes itself since a portion of the signal is extracted from the vertical amplifier and injected into the sweep generator.

A complete treatise on the use of the oscilloscope is beyond the scope of this Chapter. Herein is included, however, some few basic operational procedures which may well serve as a guide to the serviceman who has not used the instrument extensively.

Controls—The following controls are normally to be found on the oscilloscope:

1. Vertical gain, coarse.
2. Vertical gain, fine.
3. Horizontal gain.
4. Timing, coarse.
5. Timing, fine.
6. Sync control.
7. Focus.
8. Intensity.
9. Vertical centering.
10. Horizontal centering.
11. Sync-selector switch.

The meaning of these labels is doubtless self-evident. Proficiency in their use, particularly in connection with 4, 5 and 6 comes only with practice. Perhaps the greatest difficulty that will be experienced, aside from the proper interpretation of the reproduced trace, will be that of obtaining stability of the trace; a function of the three aforementioned controls.

Perhaps the most outstanding cause of failure to consistently obtain a stable pattern lies in the use of excessive synchronizing potentials, which may cause irregular synchronization and the loss of a portion of the desired sweep trace. In adjustment, it is improper to vaguely set the timing (sweep repetition rate) controls and to attempt final stabilization by greatly advancing the sync control. Rather, the sync control should be first adjusted to a moderate value and the picture stabilized by the fine-timing control. Should insufficient sync then be had, as evidenced by inability to "stop" the picture, then the sync control may be advanced slightly and the fine-timing control readjusted.

It should be remembered that, for a single cycle of reproduction, the oscilloscope sweep repetition rate must be equal in frequency to that of the waveform being observed. For two cycles of reproduction, it must be one-half. Most waveforms presented in service manuals and in manufacturer's literature show two cycles of the signal.
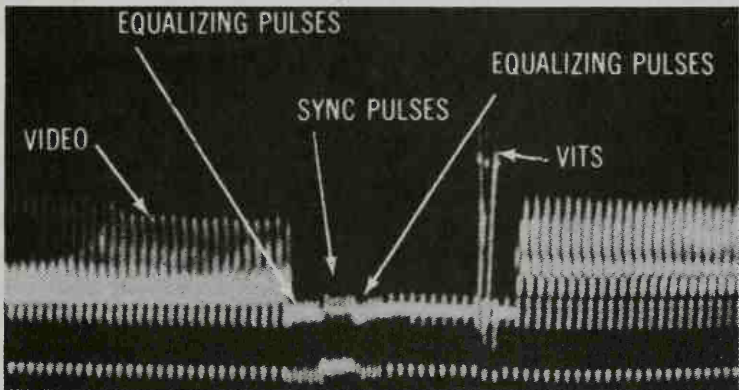
Fig. 2. Display of the vertical interval test signal (without horizontal expansion).

Necessary Characteristics—The characteristics of a test oscilloscope must of necessity be considered prior to its use for alignment and troubleshooting of a television receiver. Some of these are given in the following:

Frequency Response — Generally commercial oscilloscopes, depending upon the particular design, have a low-

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frequency limit somewhere between 10 and 100 Hertz, and a high-frequency limit of between one-hundred thousand Hertz and five megahertz. If the vertical-interval test signal (VITS) is to be displayed, triggered sweep is required in addition to 4.5 MHz response. (See Fig. 2).

It is sometimes erroneously contended that since video frequencies in excess of 4 MHz are encountered, the oscilloscope must be responsive to this limit. Stress is placed upon the wide passband of some instruments in promotion literature. There are, in laboratory usage, instruments extending as high as 20 or 30 MHz which are advantageous in specialized applications. At the same time, there are instruments giving practical satisfactory performance, whose response extends only to 75 or 100 kHz.

It should be realized that in general testing and servicing of monochrome receivers, it is of no advantage to observe the higher frequency component of the video signal. These are the impulses which reproduce the fine detail of the image and which can only be interpreted from the face of the picture tube itself; their presence in the oscilloscope reproduction of the video signal means nothing.

Secondly, limited high-frequency response will cause a rounding-off of the sync pulses; therefore the question is primarily how high it will be necessary to go in order to satisfactorily reproduce these.

In design and laboratory applications, it is often necessary that exactly true visualization of the wavefront be obtained, and that harmonics in the order of 120 or more be present.

Receiver testing, however, permits some distortion and, furthermore, the high-frequency response of the sync circuits themselves are quite low. A typical circuit may use a plate-load resistor of 68,000 ohms and have a lumped capacity to ground of 50 mmf.

This gives a high-frequency cutoff of

$$f = \frac{1}{2\pi RC} = \frac{1}{6.28 \times 68{,}000 \times 50 \times 10^{-12}} = 46{,}800 \text{ Hertz.}$$

From this it follows that it would be of no particular advantage to use an oscilloscope whose frequency range extends to 5 MHz in such an application.

High frequency response in the vertical deflection amplifier might well be, for general testing and servicing, essentially flat to 100 kHz. Beyond this, the added cost is not justified by increased utility.

In the servicing of color receivers, it is sometimes necessary to observe signals at the color subcarrier frequency of 3.58 MHz. An oscilloscope response of 4 to 5 MHz is necessary.

Low-frequency response is an item often neglected in considering the oscilloscope, yet it may be such that distortion is introduced. With poor low-frequency response resulting in a large amount of distortion it is naturally impossible to judge the circuit under test and the reproduced pulse values are therefore of no value.

The Input Cable—The input cable should always be of as low capacity as possible. Ratings are in a given number of mmf. per foot of length. The impedance of the cable is of no consequence when working at the signal frequencies encountered. It is to be anticipated that high impedance and low capacity are inseparable, but in any given cable of 100-ohms impedance, various capacities are represented. The choice of a cable, should therefore be upon the basis of capacity only, and should not be excessively long.

Oscilloscope Loading—Quite often it is desirable to expand the horizontal sweep so that it extends far beyond the limits of the screen. This calls for an amplifier which is capable of developing sweep potentials greatly in excess of that necessary to the three to five inches of active screen. Then there is the likelihood of overload and compression of the sweep at either or both ends. This may or may not be apparent by mere observation of the trace, but may be definitely determined by placing a signal upon the vertical plates; this signal could, for a simple test, be had by simply placing a finger upon the vertical-input terminal. The horizontal amplifier should be such that this

overloading condition is not apparent with horizontal sweep at its maximum and the horizontal positioning control rotated to extreme limits.

Testing the Oscilloscope—If it is desired to test the vertical response of an instrument prior to purchase, or to determine its true operation in application, this may readily be done by applying to the vertical input the output of a variable-frequency square-wave generator. Provided that the generator output is a true square wave, any departure therefrom on the screen is indicative of faulty operation. Frequencies should be between 30 and 15,000 Hertz.

Should there be no distortion whatsoever, the vertical amplifier response is acceptable. By distortion is meant that the reproduction should not depart from the square wave, that is, the leading and lagging edges should be fairly straight, the corners square, and the baseline straight.

Other Features—Other features of the oscilloscope are more or less optional. It may have a three- or five-inch screen, although those with three-inch screens are usually somewhat limited in other necessary requisites, due to economical considerations.

Some instruments have provisions for internal sync at 60 Hertz, and an associated phasing device permitting the pattern to move along the frequency or time axis. These may readily be provided, however, by external devices of simple construction. It is immaterial whether the tube deflection plates be brought out to external connections, since these have little application in receiver testing.

Also the so called "Z" axis is of little consequence in television testing work. This is a connection, either directly or through an amplifier, to the control grid of the oscilloscope tube. Its function is to cut off the beam at some desired time, for example, one of the two traces obtained from sweep-generator operation may be eliminated by the application of a negative potential to this grid during the time of one of the traces. Most sweep generators now provide this blanking function internally.

After a technician has become thoroughly familiar with the operation of a conventional scope, he may wish to investigate the facilities provided by a triggered-sweep scope, such as illustrated in Fig. 3. For example, an expert operator can use this type of scope to pick a color burst out of a

Courtesy B&K Precision, Div. of Dynoscan Corp.

Fig. 3. A triggered-sweep scope.

waveform, and expand the burst display on the scope screen. This is a useful procedure when checking out a color-bar generator, for example. However, it must be emphasized that the most elaborate scope will not be of much use to a technician who lacks an understanding of circuit action and waveform analysis. The ability to interpret waveform distortions can be gained only by persistent study and experience.

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Sweep Generator—In television testing and alignment, the requisites of the sweep generator are far more stringent than in other types of work, due to the higher frequencies and increased sweep width required. A typical sweep generator is illustrated in Fig. 4.

Courtesy Sencore Inc.

Fig. 4. The Sencore sweep generator.

Center Frequency—The requisites for "center frequency" is that the generator should cover at least to the highest intermediate frequency of television receivers, that is, slightly under 50 MHz. This is a minimum requirement, and it should preferably extend also to the RF ranges of 220 MHz.

Sweep Width—The sweep excursion must be somewhat in excess of the greatest bandwidth encountered in television, which is 6 MHz. A sweep width of not less than plus and minus 4 MHz (8 MHz overall) with plus and minus 8 or 10 MHz being a more desirable range. Should the sweep

excursion be too narrow, then the reproduced traces will be excessively broad and they may not include the adjacent-channel frequencies at which traps are sometimes placed. As a consequence the two reproduced traces will merge into one where the sweep is very inadequate. A comparatively elaborate sweep generator is shown in Fig. 5.
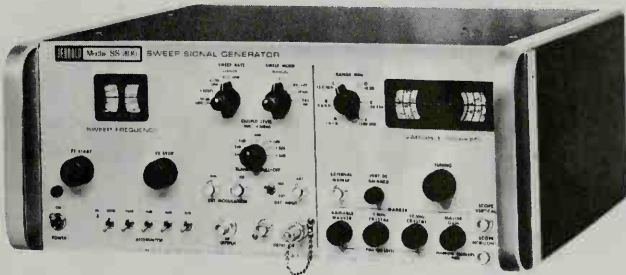
Fig. 5. A lab-type sweep generator.

Signal Generator—If the sweep generator does not incorporate internal marker circuits, it will be necessary to employ a separate signal generator (without modulation) as a means of identifying frequencies within the reproduced trace. As such, its calibration must be quite accurate. In fact it is recommended that a crystal calibrator be frequently used, since the calibration of most service type signal generators changes from time to time. A crystal controlled calibrator is shown in Fig. 6.

In television servicing the frequency range of the generator should be great enough to include all television channels, so that the generator can be used to supply test signals at the picture and sound carrier frequency for each television channel on which receivers will have to be adjusted.

The commercial FM broadcast band of 88 to 108 MHz should also be included. If the frequency range of the generator is restricted, it may be possible to use harmonics of the output signal for the higher frequencies. Actually, many

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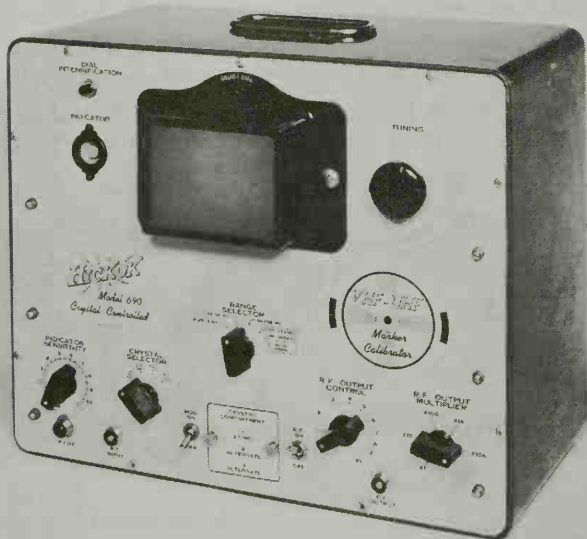
Fig. 6. The Hickok 690 television calibrator.

signal generators use harmonics of a lower range to provide frequencies in the highest range.

Signal tracing through the receiver circuit may be carried out with this generator as in conventional receivers, working back toward the antenna, stage by stage to localize a defective stage.

When employing the 400-Hertz output in the audio and video stages and the modulated RF signal in the IF and RF stages, the indication of normal operation is a steady tone from the loudspeaker in the sound channel while horizontal bars are produced on the screen of the picture tube for signals in the picture channel.

The audio test signal is also useful when non-image methods of testing scanning linearity must be employed to produce horizontal bars in the picture for checking vertical linearity. A test signal frequency of about 157.5 Hertz can be used to check horizontal linearity.

Aside from frequency range and stability of calibration, there are two other points to be considered. First the output should be about one volt at a maximum, and attenuation down to almost zero or about one microvolt should be provided. Leakage is checked by connection to a sensitive receiver operating at full gain, then reducing the generator attenuator. The signal should then reduce to an imperceptible level.

Secondly, the oscillator should be quite stable when used as a marker. Any factor which leads to instability of the oscillator within the signal generator, leads to unsatisfactory results.

Marker Systems—Specifically a marker system consists of an accurately calibrated signal source, which can be
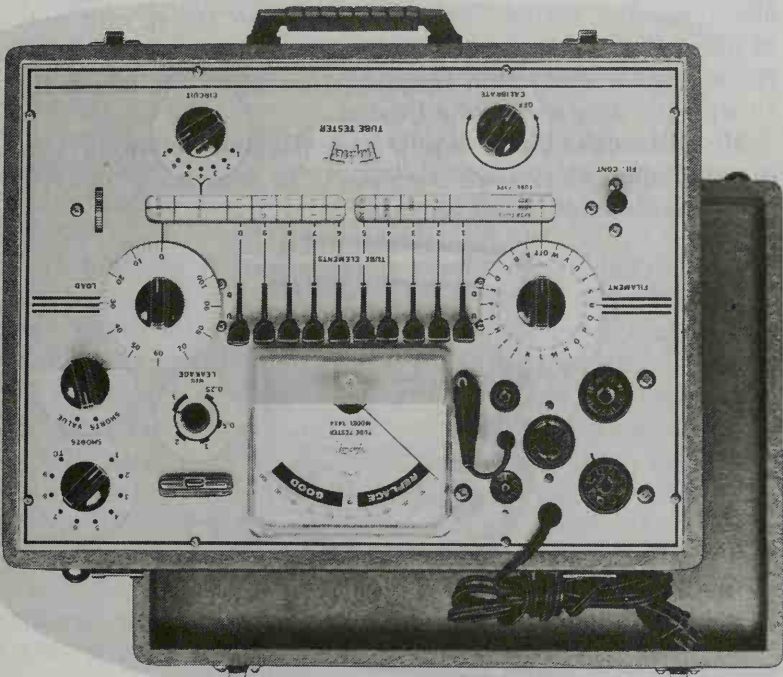
Courtesy Triplett

Fig. 7. A service-type tube tester.

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internal or external to the sweep generator. This calibrated source may take the form of a crystal oscillator of various frequencies which can be switched in and out permitting the calibration of the curve or it can be a continuously variable accurately calibrated signal generator.

There are numerous marker generators on the market. When properly designed this is a precision instrument whose function is to produce highly accurate marker "pips" to show specific frequency locations on a tuned-circuit response curve on the oscilloscope.

The need for an accurately calibrated marker system will be seen by the fact that any response waveform, as reproduced on the oscilloscope screen, is only approximately calibrated. The center of such a trace represents the center frequency at which the sweep generator has been set. Without a marker system, extremities of the sweep can only be approximated by adding and subtracting from the center frequency the maximum frequency deviation for which the sweep generator has been adjusted.

Miscellaneous Test Equipment Items—Following are certain additional items necessary to television receiver maintenance and trouble shooting:
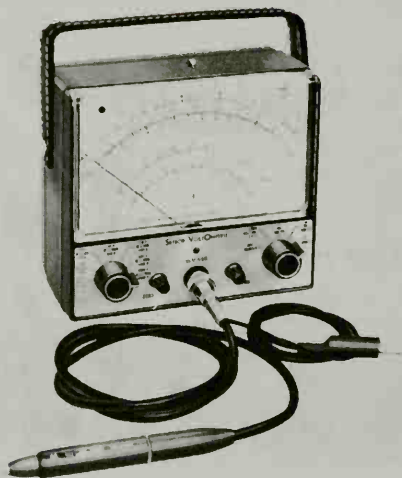
Fig. 8. The RCA WV-98B VTVM.

The *tube tester* should preferably be of the dynamic type, checking mutual conductance (Gm) of all types used, including the miniature types. A service-type tube tester is illustrated in Fig. 7.

A *universal meter*, reading volts, ohms, milliamperes, etc., should be of the high-impedance type (Fig. 8) (20,000 ohms per volt or better) and may be used also in reading high voltage by applying a multiplier. There are available high-voltage cables and test prods which have built-in multipliers to extend the range of the meter to any reasonable value. (See Fig. 9).

There has been a trend toward the use of digital voltmeters (DVM's) in service shops. (See Fig. 10).

There are many *CRT testers* on the market. These give a simple GOOD-BAD indication based on amount of cathode emission. Many of these instruments also provide a means of "rejuvenating" the CRT to extend its useful life. See Fig. 11.

Monochrome picture tubes have acceleration potentials approaching 16,000 volts; this should be the minimum requirement in HV meters. Color receivers will use up to 30 KV.

It must be borne in mind that even 50 microamperes drain (at full scale of the meter) may drop the high voltage appreciably. This may be ascertained by observing change in picture size. If the picture materially increases in size as the reading is being taken, some allowance must be made for reduction under test. The only true measure, in such a case, is by an electrostatic DC voltmeter, an instrument usually restricted to the laboratory due to cost factors.

Variable Voltage Transformer—A variable voltage transformer is necessary for proper voltage control. Picture size and brillance are dependent upon line voltage; changes are more apparent in some receivers than in others. Also, it has been noted that the line voltage in most service areas is variable over wide limits. There should be, therefore, in adjusting the receiver, some means of simulating the actual operating conditions encountered in the

LC-32 OPTIONAL CASE

Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 9. A high-voltage DC probe with a built-in meter.

Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 10. A typical digital multimeter.

field. The transformer should be at least of five-ampere size. The transformer should be the isolating type with no connection between primary and secondary. The use of an isolating transformer eliminates the shock hazard during servicing of AC-DC chassis, which have one side of the line connected directly to the chassis.

Small Tools—These, including alignment tools, are essentially the same for any type of receiver whether AM, FM or television.

Mirror—In servicing television receivers, a mirror is often used for observation of the picture screen while making adjustments at the rear of the chassis. To prevent breakage, this may be a metallic sheet, possibly a ferrotype plate, obtainable at any photographic supply house.

Fig. 11. The B&K 440 cathode-ray tube tester and rejuvenator.

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Detector Probe—In checking operation or alignment in a single IF or RF stage, detection must be had before application to the oscilloscope. The detector probe may contain a tube or a crystal, as long as it does not seriously introduce capacity into the circuit.

COLOR TEST EQUIPMENT

All of the aforementioned items of test equipment are applicable to the servicing of color receivers. A few special pieces of test equipment are intended specifically for color servicing.

White-Dot Generator—This instrument produces white dots on the screen of the receiver to permit adjustment of CRT convergence. An alternative output is a crosshatch of white lines. These outputs are available as a video signal (to be injected into the video-amplifier circuit) or as an RF signal (to be injected into the antenna terminals). Many instruments of this type also produce color bars.

Color-Bar Generator—The final check after servicing of a color receiver is to see that it reproduces colors correctly.
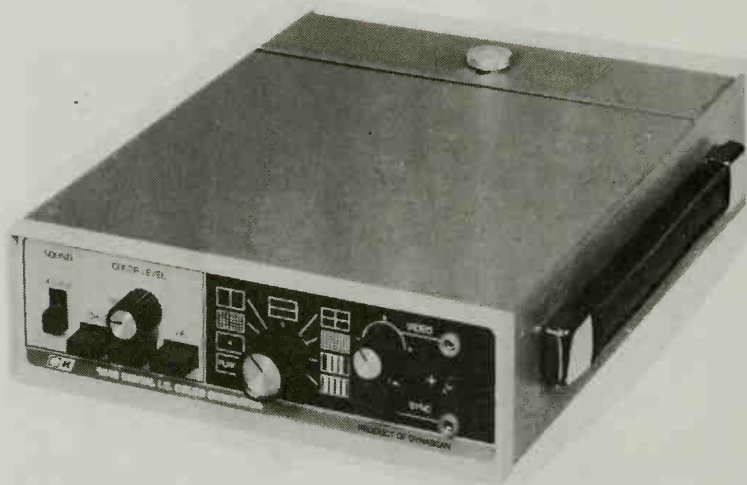
Courtesy B&K Precision, Div. of Dynascan Corp.

Fig. 11. A digital IC color generator.

The color-bar generator, produces on the screen, a series of vertical bars of different colors. If the receiver reproduces these in the proper sequence (both saturation and hue) the color circuits are working properly. A typical color-bar generator is illustrated in Fig. 12.

VECTORSCOPE

A vectorscope is basically an oscilloscope which is applied in certain ways to check chroma demodulator or matrix circuit action. For example, suppose that we apply an unkeyed rainbow signal to a color-TV receiver, and connect a scope at the outputs of the R-Y and B-Y demodulators, as shown in Fig. 13. An unkeyed rainbow signal is simply a 3.56-MHz sine wave, with or without sync pulses, as illustrated in
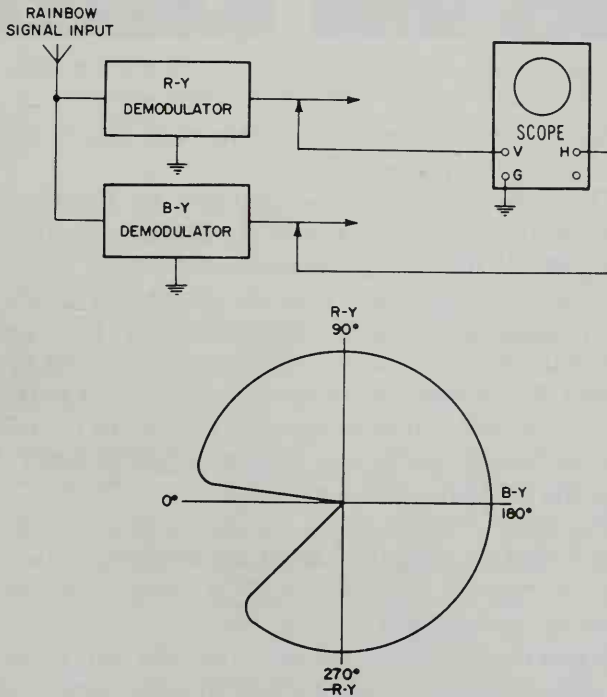
Fig. 13. Simple rainbow vectorgram.

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Fig. 14. In turn, a pattern is displayed on the scope screen as depicted in Fig. 14B. Note the following characteristics:

1. The basic pattern is a circle, with a "pie cut" representing the horizontal blanking pulse.

2. A circular pattern is produced because the demodulated 3.56-MHz sine wave is applied to the vertical deflection plates of the CRT in a reference phase, and is
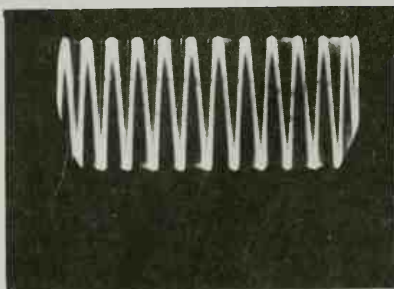
(A) No sync pulse (Expanded Sweep).   (B) With sync pulses.
Fig. 14. Output from an unkeyed rainbow generator.
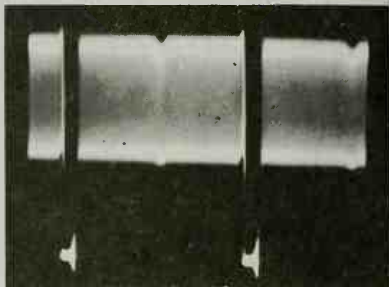
applied to the horizontal deflection plates at a 90° difference in phase.

3. The pattern will not be distorted by the scope, provided that the vertical and horizontal amplifiers have negligible frequency and phase distortion.

4. If the vertical and horizontal amplifiers in the scope introduce appreciable distortion, the R-Y and B-Y signals must be fed directly to the deflection plates in the CRT in order to obtain an undistorted pattern.

Next, if a keyed rainbow signal is applied to the color-TV receiver, a "petal" pattern is displayed, as depicted in Fig. 15. Note the following characteristics:

1. The basic pattern has a circular outline, with a "pie cut" representing the horizontal blanking pulse.

2. Each "petal" corresponds to a certain chrominance phase, as depicted in Fig. 16.

3. Direct coupling is required to the CRT deflection plates in most cases, because horizontal amplifiers in service-type scopes seldom have sufficiently good frequency

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and phase response to reproduce the "petal" wave-forms without distortion.

In case we apply an NTSC color-bar signal to the color-TV receiver, another type of vectorgram pattern is displayed, as depicted in Fig. 17. Note the following characteristics:

1. Each corner of the vectorgram pattern corresponds to a particular color-signal phase, as shown in Fig. 18.
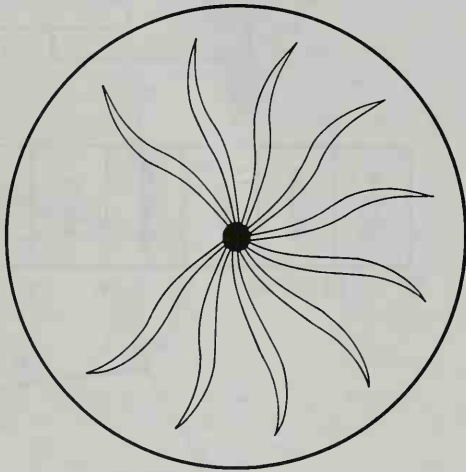
Fig. 15. Keyed rainbow vectorgram.
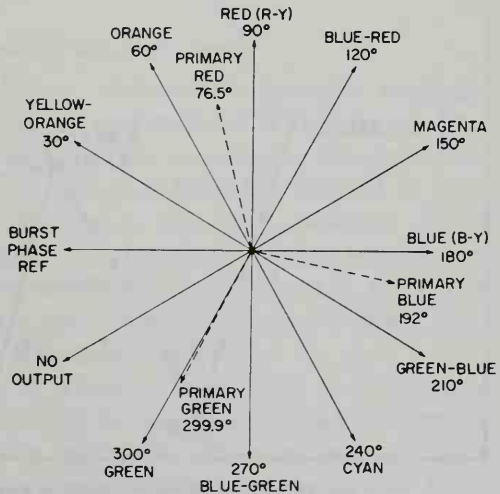
Fig. 16. Phase progression of a rainbow signal.
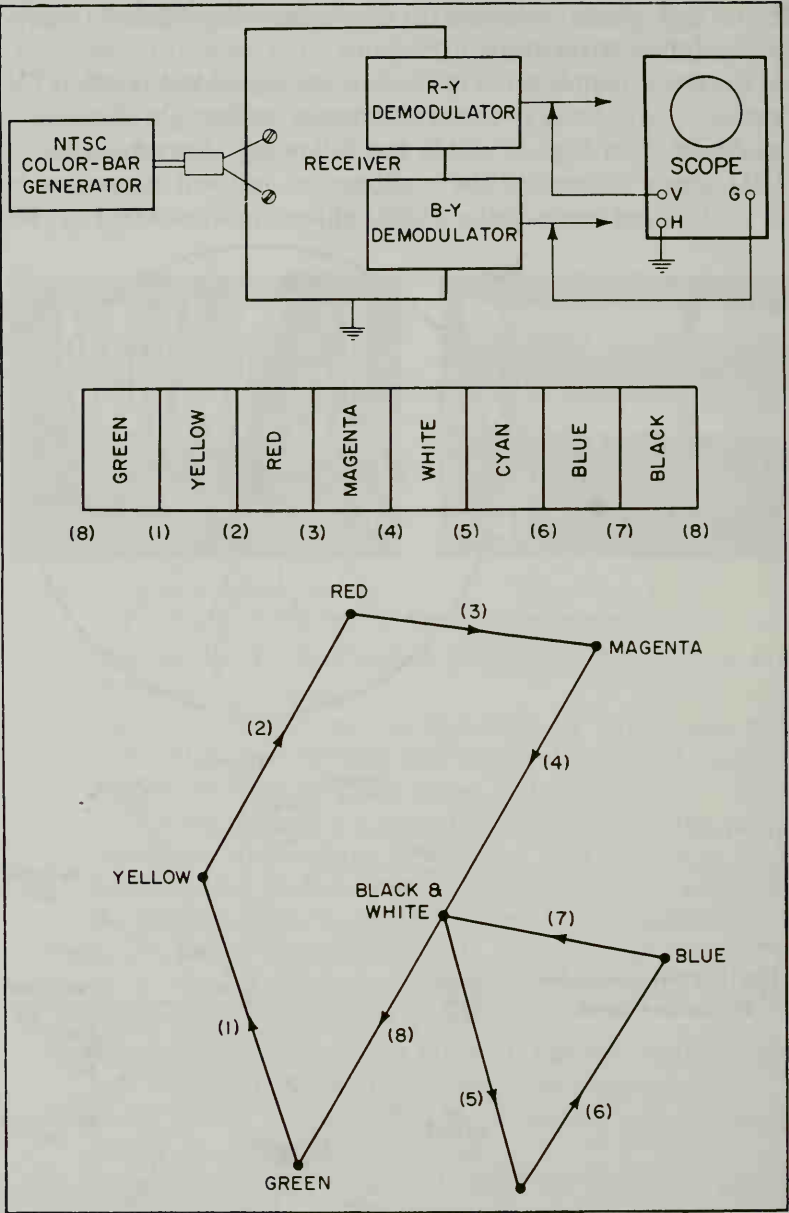
Fig. 17. Display of chroma phase in a vectorgram pattern.

2. The distance of each corner from the center of the pattern indicates the relative amplitude of the particular color signal.

3. Direct coupling to the deflection plates of the CRT is required with most service-type scopes, to avoid distortion of the vectorgram pattern.
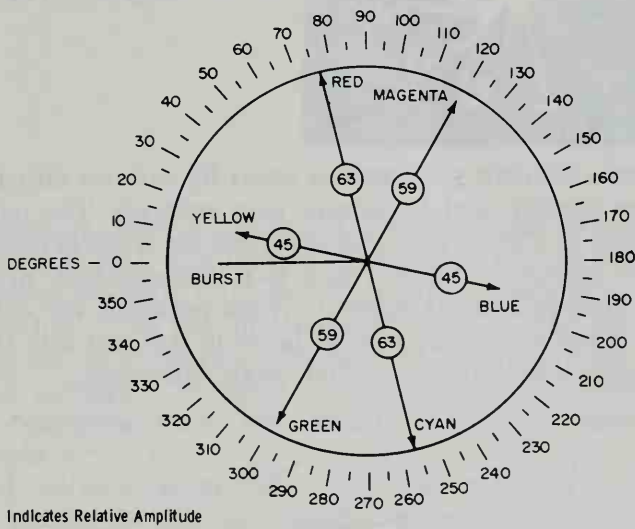
Fig. 18. Vector relationships.

Fig. 19 shows photos of vectorgram patterns obtained with a keyed-rainbow signal and with an NTSC signal. The chief disadvantage of using direct coupling to the deflection plates in the CRT is the fact that tests are limited to comparatively high-level circuits in the color receiver. About 100 volts p-p are required to obtain a sizable screen pattern when driving the deflection plates directly. However, if a scope with adequate amplifiers is used, vectorgram tests can be made in low-level receiver circuits.

Another advantage of using a scope that has adequate amplifiers is that the gains of the vertical and horizontal channels are individually adjustable. Thus, patterns such as shown in Fig. 20 can be placed into standard circular form

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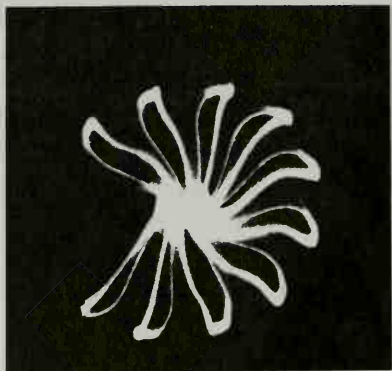
Fig. 19.Vectorgram pattern from a
keyed-rainbow color-bar signal.

(when a rainbow generator is used) by suitable adjustment
of the vertical and horizontal gain controls. The patterns
depicted in Fig. 20 are obtained when the scope is connected
at the outputs of the R-Y and B-Y demodulators, provided
that demodulation is normal. These patterns are obtained
only if the subcarrier voltage is being injected into the de-
modulators with the normal 90° phase difference.
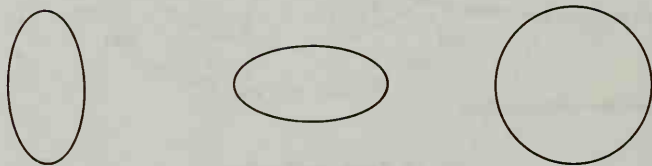
(A) Vertical ellipse. (B) Horizontal ellipse. (C) Circle obtained by suitable vertical or
horizontal gain-control adjustment.

Fig. 20. Scope connected at output of R-Y and B-Y demodulator.

On the other hand, if there is a defect in one of the de-
modulators, and the injected subcarrier voltages do not have
a 90° phase difference, a diagonal ellipse is displayed, as
depicted in Fig. 21. Note carefully that a diagonal ellipse
cannot be placed into standard circular form by adjustment
of the scope's vertical and horizontal gain controls. No
matter how we adjust the gain controls, we still have a
diagonal ellipse displayed on the screen. Let us see how
diagonal ellipses are evaluated.

In Fig. 21, the diagonal ellipse has been exactly centered
on the scope screen by suitable adjustment of the vertical

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Fig. 21. A method for calculating the phase angle represented by a 1-to-1 Lissajous figure.
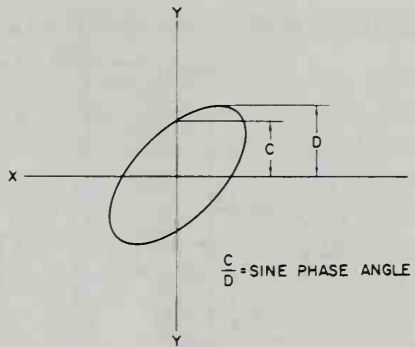
$\dfrac{C}{D}$ = SINE PHASE ANGLE

and horizontal centering controls. We count squares to measure the lengths C and D. Then, the sine of the phase angle is given by the ratio C/D. In the example shown, this ratio is about 0.8. If we look in a table of sines, we find that the sine of $53°$ is approximately equal to 0.8. Therefore, the injected subcarrier voltages in this example do not have a phase difference of $90°$, but instead, they have a phase difference of $53°$.

Next, let us consider the vectorgrams normally obtained when testing the XZ demodulator system depicted in Fig. 22. If the vertical input to the scope is taken from test point A, and the horizontal input is taken from test point C, we obtain a pattern such as shown in Fig. 15. On the other hand, if we test at the plates of the X and Z demodulators, we obtain a diagonal ellipse. This is because the demodulation phases are separated by $63.9°$, as depicted in Fig. 21B. With reference to Fig. 21, the ratio C/D will be approximately 0.93.

Suppose that the vertical input to the scope is taken from test point A, and the horizontal input is taken from test point B in Fig. 22. The G-Y signal is $236.4°$ from burst, or we will obtain a diagonal ellipse with reference to an angle of $236.4°$ minus $180°$, or $56.4°$. The ellipse will have almost the same C/D ratio as in Fig. 21, but the pattern will incline to the left, instead of inclining to the right.

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(A) Schematic diagram.

(B) X and Z demodulation system.
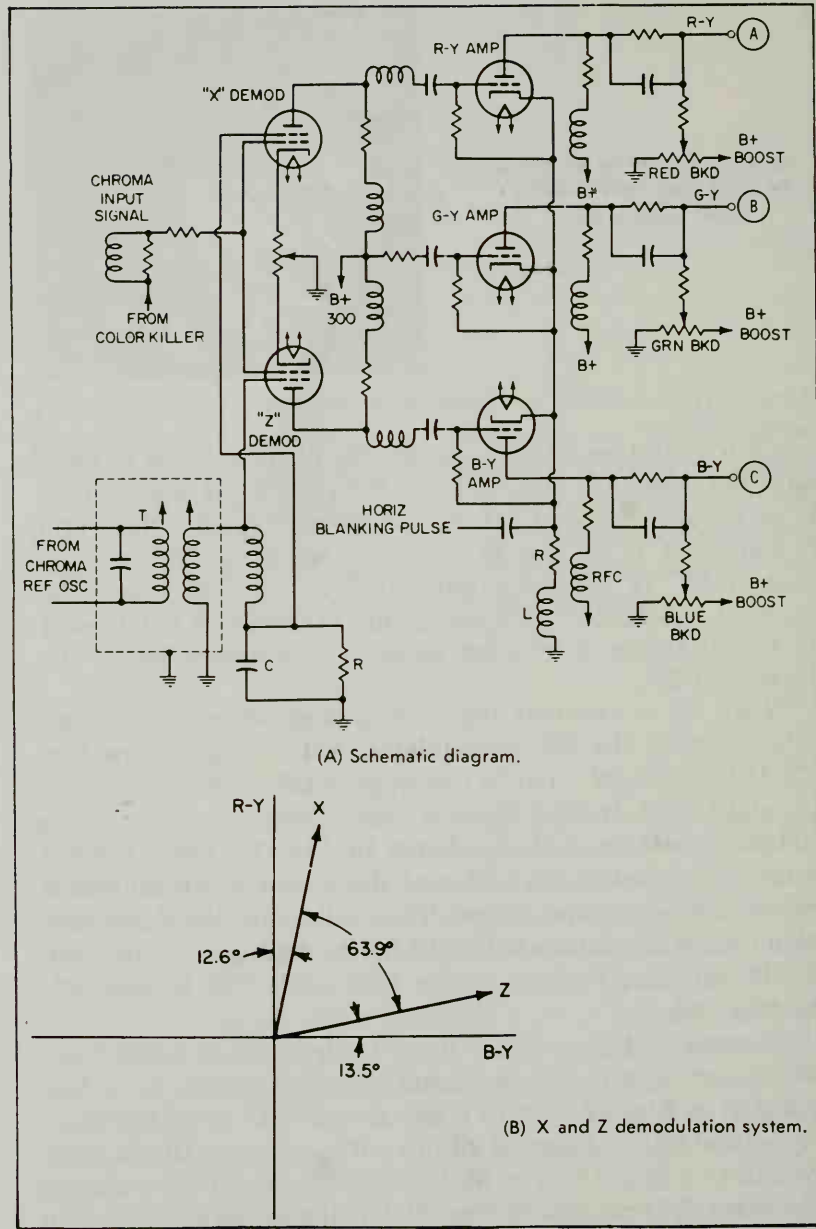
Fig. 22. The X-Z chroma-demodulation system.

OSCILLOSCOPE AND VECTORSCOPE GRATICULES

A graticule is a ruled transparency placed over the CRT face, to facilitate waveform analysis. The graticule may also provide filtering for better contrast under ambient lighting conditions. For example, scope graticules are often green transmission filters. Some graticules are edge-lighted, so that the rulings are clearly visible in low ambient lighting. Fig. 23A illustrates a basic graticule ruling; this is simply a Cartesian coordinate plane. Again, only X and Y coordinates may be ruled on the graticule, as shown in Fig. 23B. Or, peak-to-peak voltage values may be indicated along the vertical axis, as seen in Fig. 23C. If an oscilloscope has a choice of narrow-band and wide-band response, dual voltage scales may be provided, as shown in Fig. 23D.

Fig. 24 depicts a typical vectorscope graticule. This type of graticule is used with a keyed-rainbow signal. Ten "petals" are displayed on the screen, as illustrated in Fig. 19. Therefore, ten phases are marked on the graticule; the R-Y and B-Y phases are indicated by small circles. The pattern is normally adjusted so that the third petal terminates in the R-Y circle, and the sixth petal in the B-Y circle. Sometimes the burst phase is also indicated, as seen in Fig. 25; in this example, triangles are used instead of circles to denote the R-Y, B-Y, and burst phases.

When an NTSC color-bar signal is used, the vectorscope graticule is ruled as shown in Fig. 26. Phases are indicated for burst, yellow, red, magenta, blue, cyan, and green. The small circles are also spaced from the center of the graticule to show the normal relative amplitudes of the color signals. Note that the burst phase will not be indicated in a vector-gram display if the burst is blanked out prior to chroma demodulation. This depends on the design of the color-TV receiver. In some receivers, the burst passes through the chroma demodulators, and is indicated in the pattern. When the burst is blanked prior to demodulation, the residue of the blanking pulse is displayed. However, this residue has an arbitrary phase, and does not denote the burst phase as such.
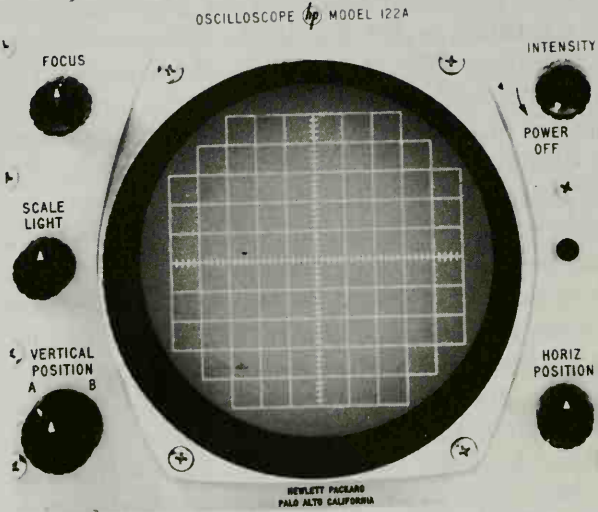
Courtesy Hewlett-Packard.

(A) A basic graticule ruling.
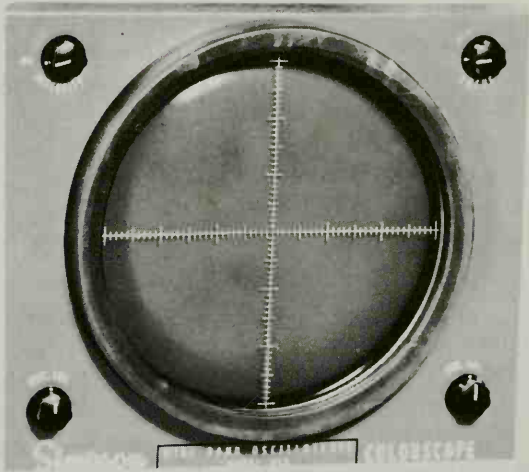
Courtesy Simpson Electric Co.

(B) X and Y coordinates only.

Fig. 23. Scope
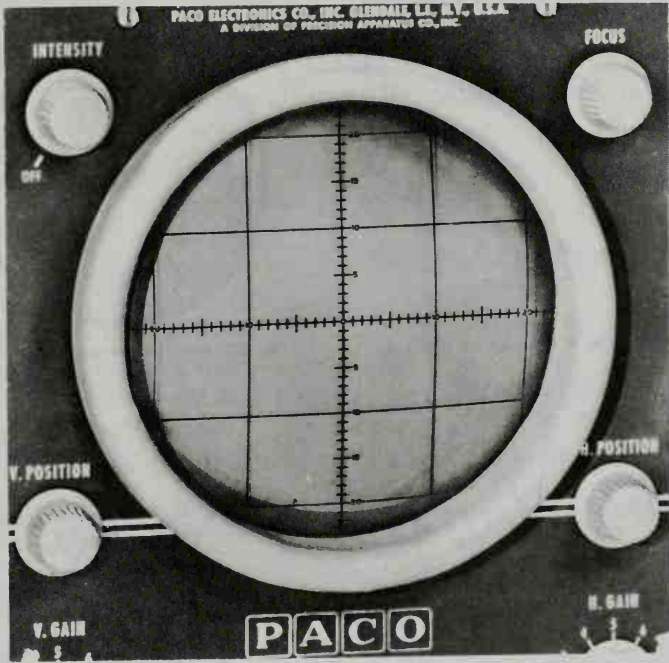
Courtesy Paco Electronics.
(C) Peak-to-peak voltage values indicated.
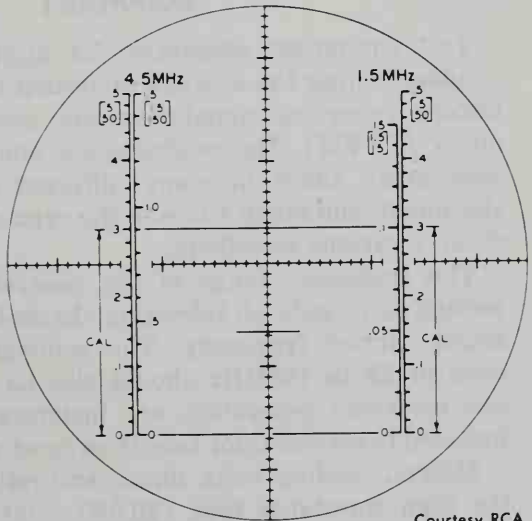
(D) Dual voltage scales.

Courtesy RCA.

graticule rulings.
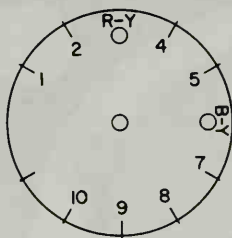
Fig. 24. A vectorgram graticule.
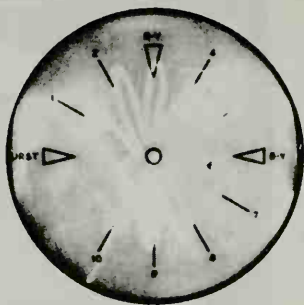
Fig. 25. Another vectorgram graticule.
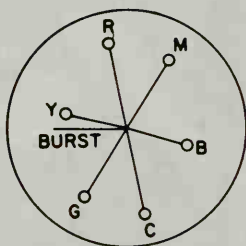
Fig. 26. Vectorgram graticule
for an NTSC signal.

SUMMARY

Test equipment necessary for alignment and effective troubleshooting the average television in the shop are oscilloscope, sweep and signal generator, and a vacuum tube voltmeter (VTVM). The oscilloscope is one instrument which is used many times in many different operations, such as alignment, and many times in the sync and sweep circuits to observe various waveforms.

The frequency range of the generator should be great enough to include all television channels at the picture and sound carrier frequency. The commercial FM broadcast band of 88 to 108MHz should also be included. White-dot and color-bar generators are instruments which must be included to service color television receivers.

Meters, reading volts, ohms, and milliamperes should be the high-impedance type (20,000 ohms per volt) and may be used to read high voltage with the use of a multiplier.

Dynamic type tube testers should be used to check the mutual conductance of all tubes, including the miniature type.

REVIEW QUESTIONS

1. What two instruments are necessary to align a television receiver?
2. What are the four basic instruments needed for trouble-shooting and alignment procedure?
3. What are the low and high frequency response of commercial oscilloscopes?
4. What should the frequency range of a signal generator be?
5. What are the requirements for a good VTVM?

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Appendix

A glossary of television terms most commonly used is presented on the following pages. These terms will assist the reader in acquiring knowledge in interpretation of the function of the numerous components involved as well as to review the numerous technical terms used in the text.

Absorption Trap. A parallel-tuned circuit coupled either magnetically or capacitively to absorb and attenuate undesired frequencies.

Accelerator. The second anode of a cathode-ray tube. This anode, operated at a high positive potential with respect to the cathode, increases the velocity of the electron stream and is therefore referred to as an accelerating anode.

Accompanying Audio (Sound) Channel. The RF carrier frequency which supplies the sound that accompanies the picture. Also called co-channel sound frequency.

Active Lines. The lines which produce the actual picture, as distinguished from those which occur during the blanking time.

Adjacent Audio (Sound) Channel. The RF carrier frequency which carries the sound modulation associated with the next lower-frequency television channel.

Amplitude Separation. Separation of signal components by virtue of their various amplitude excursions, usually accomplished by means of a clipper.

Aperture Mask. A thin sheet of perforated material placed directly behind the viewing screen in a three-gun color picture tube to prevent the excitation of any one color phosphor by either of the two electron beams not associated with that color. Also called Shadow Mask.

Aquadag Coating. A conductive coating formed by a colloidal solution of carbon particles on the surface of the glass envelope of picture tubes. It is also placed on the inside of the tube to collect secondary electrons emitted by the fluorescent screen. On the outside of the tube, it forms one plate (with the inner coating the second plate) of a capacitor for the high-voltage filter circuit.

Array. A combination of antennas.

Aspect Ratio. The ratio of the width to the height of a television picture. Under present television standards, the picture aspect ratio is 4 to 3.

Background. Average illumination of a scene.

Bands. This refers to a group of continuous frequencies occupying "room" in frequency space.

Bandpass Filter. An electrical network designed to transmit a band of frequencies and to reject all other frequencies.

Beam Current. The current in the stream of electrons in the cathode-ray tube. The beam current rarely exceeds 250μa and is normally less than 100μa.

Black Level. In the television receiver, the video signal is applied to the cathode-ray tube. Portions of this signal drive the tube to cutoff and produce the black portions of the picture. Those portions of the video signal which drive the tube beyond cutoff are said to be below the black level.

Blacker than Black. The region of amplitude excursion of the video signal which corresponds to levels lower than black in the picture. These are not seen on the picture tube when the background is correct. This region is occupied by sync signals.

Blanking. The process of applying voltage to the cathode-ray tube to cut off the electron beam during the retrace or flyback period.

Blanking Pedestal. A voltage pulse used to drive the cathode-ray tube beyond cutoff during the time the spot is returning from right to left or from the bottom to the top of the picture. These blanking pedestals must be synchronized with the sweep circuits so that the beam is cut off at the right time.

Brightness. The intensity of the light produced at the screen of a cathode-ray tube.

Brightness Control. In the television receiver, the adjustment which varies the average illumination of the picture by varying the bias on the cathode-ray tube.

Brilliance. Same as brightness.

Cathode-Ray Tube. An electron tube which converts electrical energy into light by projecting a beam of electrons upon a fluorescent screen. The screen glows at the point where the electrons strike it, producing a spot of light. By deflecting the electron stream, the spot may be made to trace a pattern corresponding to the deflection voltage.

Centering. The process of moving the center of the image to coincide with the center of the cabinet opening which frames the picture.

Centering Control. An adjustment for moving the raster electrically in either a horizontal or vertical direction for framing the image.

Clamper. A circuit which establishes the DC level of a waveform (the baseline of an AC wave with a DC component). Clampers are also known as DC restorers.

Clipper. A circuit designed to remove all of a waveform above or below a given level.

Clipping Level. The amplitude level at which a waveform is clipped.

Contrast Control. An adjustment for increasing or decreasing the range of light intensities of an image by varying the amplitude of the

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picture signal. Contrast control in the television receiver corresponds to gain control in a sound receiver.

Composite Signal. A television signal whose waveform is composed of both video and synchronizing signals, each having different amplitude excursions.

Composite Sync. A signal composed of horizontal sync signals, vertical sync signals, and equalizing pulses.

Contrast. The total range of light intensities between the darkest and brightest portions of an image on the television screen.

Cutoff Frequency. A frequency beyond which no signals are transmitted or utilized. It may refer to an upper limit, a lower limit, or both.

Deflection. A process whereby an electron beam is deviated from its straight-line path by means of an electrostatic or electromagnetic field.

Deflection Coils. Coils placed around the neck of a cathode-ray tube to deflect the electron stream. The magnetic field created by the flow of current through the deflection coils causes the electron stream to deviate from its normal path. This system is electromagnetic deflection.

Demodulation. The derivation of a waveform having substantially the same form in time as the amplitude or frequency modulation of a carrier.

Differentiating Circuit. A circuit arranged to derive an output potential which is proportional to the time rate of change of the input current.

Dipole. A linear conductor whose length is approximately one-half the optimum wavelength of resonance, generally used as a television antenna. It is usually divided in the middle into two arms, where the impedance is lowest (72 ohms theoretically) for connection to a transmission line lead-in.

Director. A dipole placed in front of a dipole antenna, toward the transmitter, to narrow the angle of reception in order to obtain greater directivity. No connection is made to a director.

Dissector. A type of pickup tube used in the television camera, more properly referred to as an image dissector. The scene to be televised is focused through a system of lenses upon a photosensitive surface. The electron emission from every point on this surface is directly proportional to the intensity of the light falling upon that point. Since emission takes place simultaneously from all points on the surface, an electron image corresponding to the optical image is formed. This electron image is deflected in such a manner that a small portion of it at a time passes through a window or aperture, on the other side of which is an electron-multiplier tube. The output contains signal currents corresponding to the optical image.

Double-Tuned Circuits. These are circuits resonant to two frequencies, usually closely adjacent and coupled in such manner as to show two values of peak response, approximately equal, with a dip-response between.

Dynode. An intermediate electrode between the cathode and plate of an electron-multiplier tube. The dynode emits many secondary electrons for each incident electron striking it.

Echo. Usually a pulse signal of lower amplitude than the parent primary pulse from which it originates by reflection, and occuring at a later time than the primary pulse. An echo pulse usually exhibits some phase distortion.

EIA Signal. This is a composite signal composed of video signals and EIA sync signals. It has been standardized by the Electronic Industries Association.

Electron Gun. An arrangement of electrodes inside a vacuum tube which will direct electrons from many directions, falling upon one end of it into a beam emerging from the other end. The velocity of the emerging beam may differ from that of the entering electrons.

Electron Multiplier. A device arranged to receive electrons at an input and to deliver a greater number of electrons to an output. The increase in number is due to multiplication by secondary emission in one or more stages.

Electron Optics. This refers to the treatment of electric fields as lenses for electron beams, similar to treatment of ordinary lenses in ordinary optics in regard to ordinary light beams.

Electrostatic Scanning. The deflection of electrons from a straight-line path by means of an electrostatic field of force, which depends upon the force at a distance between electric charges.

Equalizing pulses. Hroizontal sync pulses occuring at twice line frequency and of half normal duration.

Field. The picture information produced by scanning the image from top to bottom in the standard interlaced scanning system. The odd and even lines are scanned separately, thus two fields are necessary to produce the complete picture.

Field Frequency. The number of fields scanned per second. Under present television standards, this frequency is 60 fields per second.

Field Repetition rate. The number of fields transmitted per second.

Flyback. In cathode-ray tubes, the return of the spot between successive sweeps. Flyback is also known as retrace. In some oscilloscopes and in all television receivers, the cathode-ray tube is biased beyond cutoff during this period.

Fluorescent Screen. The face of a cathode-ray tube when the inside of the glass is coated with phosphor.

Focusing Control. The adjustment which varies the potential of the first anode in a cathode-ray tube. When it is properly adjusted, the stream of electrons converges to a sharp point at the exact instant it strikes the fluorescent screen.

Folded Dipole. A dipole antenna in which the outer ends of the two arms are connected together by a linear conductor, located at a small distance, one inch or so, away. Surge impedance is 300 ohms.

Frame. The total picture information contained in a scanned image. In the standard interlaced scanning system, one frame consists of

two fields. The frame frequency is therefore equal to one-half of the field frequency, or 30 frames per second.

Frequency Band. A region of frequencies, extending between limits, each frequency being adjacent to another, without gaps.

Ghost. A duplicate image on the screen of a television receiver. The ghost image is caused by a reflected signal which arrives at the receiver a short time after the direct signal.

Halation. The glowing of a phosphor on the fluorescent screen, in a region immediately surrounding the scanning spot.

Height. The amplitude of a picture in the vertical direction.

High Voltage. A potential, usually above 500 volts, utilized usually in television equipment for accelerating or speeding up an electron beam. High voltages can be dangerous to life.

Hold Controls. The adjustments which control the free-running frequencies of the horizontal and vertical sweep oscillators in a television receiver.

Horizontal. Pertaining to the line structure of a picture in a direction parallel to the ground, normally it refers to the dimensions of width.

Horizontal Blanking. The application of cutoff bias to the cathode-ray tube during the horizontal retrace.

Horizontal Centering Control. The adjustment which permits the television image to be shifted in the horizontal direction so that it may be centered on the screen.

Horizontal Flyback. The return of the spot after each horizontal sweep. It is also known as horizontal retrace.

Horizontal Frequency. The number of times per second the spot sweeps across the screen in the horizontal direction. It is also referred to as the horizontal repetition rate. In standard television practice, the horizontal frequency is 15,750 sweeps per second.

Horizontal Resolution. The number of picture elements which can be distinguished in each line of the picture.

Horizontal Retrace. The return of the beam across the width of the image after the scanning of one line.

Iconoscope. A television pick-up tube consisting of a mosaic of photosensitive elements upon which an optical image may be projected through a window, and arranged to be scanned by an electron beam which releases the stored charges in the latent image on the mosaic and produces an electrical signal in time sequence with the scanning, at an output electrode.

Image Dissector. A device for dissecting an electron image, picture element by picture element, to derive therefrom an electrical signal arranged in a time sequence.

Image Orthicon. A television pickup tube which embodies the combination of dissector and orthicon principles to produce a very high value of light sensitivity.

Integrating Circuit. A circuit arranged to derive an output potential which is proportional to the stored value of the input current over each cycle.

Interlaced Scanning. A system of scanning in which only a fraction of the image is scanned during each field. In the standard interlaced scanning system, the odd lines and the even lines are scanned as separate fields. Each field therefore contains 262.5 of the total 525 lines.

Ion. An atom having more or less than its normal number of electrons. A balanced atom has an equal number of protons and electrons. If such an atom loses one of its electrons, it assumes a positive charge (positive ion). If the atom should gain additional electrons, it assumes a negative charge (negative ion).

Ion Trap. An arrangement of magnetic fields which will allow an electron beam to pass through but will deflect ions.

Keystone Distortion. A form of distortion which causes the television image to take the shape of a trapezoid even though the mosaic in the pickup tube is rectangular. Keystone distortion is due to the fact that the electron stream does not strike the mosaic at right angles. This distortion is normally corrected in the transmitting equipment.

L/R Circuit. A time-determining circuit in which the time constant depends on the ratio of inductance to resistance.

Line. One of the strips which makes up a television image. The scanning path across the width of a television raster.

Linearity. The uniform distribution of picture elements over the total area of the image. Such uniformity can be achieved only if the sweep waveforms are linear.

Linearity Control. An adjustment in the vertical or horizontal sweep circuit which controls the linearity of the sawtooth and consequently the uniform distribution of the picture elements of the image. If the sawtooth is not linear, the spot sweeps across the screen at a varying rather than at a constant rate, with the ultimate result that the image is spread out near one edge of the picture and crowded toward the opposite edge.

Line Doubling. The technique of inserting line sync pulses at double frequency during the preparatory interval that precedes the field sync signal. The pulse width of the doubled pulses is cut in half so that integrating circuits will not store up too much energy in this period.

Line Sync. This refers to sync pulses at horizontal frequency.

Monoscope. A pattern-signal generating tube which produces in the proper circuit a time sequence of pulses equivalent to a fixed television signal. The pattern usually contains a resolution chart.

Mosaic. A photosensitive surface consisting of a large number of individual caesium-silver globules. (See Iconoscope).

Negative Transmission. Modulation of the picture carrier in such a manner that the dark portions of the image cause an increase in radiated power and the bright portions cause a decrease.

Noise. The word noise has carried over from audio practice. It refers to random signals which produce a "salt-and-pepper" pattern over a picture which is called "noisy". Also called "snow."

Nonlinearity. The crowding of picture elements from side to side, or the crowding of lines at either top or bottom of the picture.

Odd-Line Interlace. This refers to a double interlace system in which, there is an odd number of lines in each frame, and in which also, therefore each field contains a half line extra.

Orthicon. A television pickup tube somewhat similar in structure to an iconoscope but with a translucent mosaic, a collector ring instead of a backing plate for deriving output signals, and operated on different principles whereby the scanning beam is at low velocity and always at right angles to the plane of the mosaic, which practice avoids shading signals usually generated in the iconoscope.

Overcoupled Circuits. Usually two, resonant circuits tuned to the same frequency but coupled so closely as to exhibit two response peaks with a slight valley between, in order to obtain broad-band response with substantially uniform impedance.

Pairing. A partial failure of interlace in which the lines of alternate fields do not fall exactly between one another but tend to fall nearly on top of one another. The cause is usually improper timing of the field-deflection oscillator but is sometimes due to pickup of stray fields, and the result is a raster consisting of separated pairs of lines rather than with a continuous line structure.

Pass Band. A band of frequencies which is transmitted freely without intentional attenuation or reduction in amplitude of signals.

Peaking Coil. A small inductance placed in a circuit to resonate with the distributed capacitance at a frequency where it is required to develop peak response, as in a video amplifier near cutoff frequency.

Pedestal. A pulse, such as the blanking pulse, used in television systems. (See Blanking Pedestal.)

Phase Distortion. This refers to phase delays at different frequencies being of different magnitudes, which distorts peak values of the signal and spoils picture contrast and/or resolution.

Phosphor. The chemical coating deposited on the face of a cathode-ray tube. This chemical produces light when bombarded by electrons. Various chemicals are employed in practice to produce different colors.

Phosphorescence. Light given off by a phosphor after the exciting light or electron stream has ceased to act. The same as persistence and afterglow.

Photocell. A device for converting variations of light intensity or color into equivalent electrical variations.

Photoconductive. The name applied to a substance which changes its electrical conductivity under varying degrees of illumination.

Photoemissive. The name applied to a substance which emits electrons when struck by light. Caesium and rubidium are examples.

Pickup Tube. A tube used in the television camera for the purpose of converting the optical image into its electrical equivalent.

Picture Frequency. The same as frame frequency. In standard practice, the picture frequency is 30 per second.

Picture Element. An elementary area of an image field which represents one detail and is relatively uniform in illumination. The shape of a picture element in television is considered to be square,

even though the aperture of scanning spot is round, because the lines are uniform and rectilinear. The ratio of the area of an image field to the area of a picture element is representative of the detail of a television image. For a 525-line television picture, the maximum detail which can be transmitted (with equal horizontal and vertical resolution, or square picture elements) is about 330,000 picture elements.

Polarity. This refers to the direction, plus or minus, of a potential peak of a voltage. Positive polarity of a video wave at the grid of a cathode-ray tube means that the potentials are in the right direction to give a positive or normal picture. In this case the pedestals or blanking signals, have their peaks in the negative direction to cut off the beam current during the occurrence of black. Thus, in a positive picture, black is negative.

Polarization. This refers to the direction of vibration of the electric field of force in a radiated wave. The magnetic field of force is perpendicular to the electric, and so it also is defined.

Positive Transmission. Modulation of the picture carrier in such a manner that the bright portions of the televised scene cause an increase in radiated power, and the dark portions cause a decrease. Positive transmission is also called positive modulation.

Raster. The rectangular area scanned by the electron beam in the picture tube.

Reflections. This has two meanings in television; it refers to reflected waves from structures or other objects, and also to shadows in the picture produced by these reflected waves.

Reflector. A dipole placed behind a dipole antenna, away from the transmitter, to intensify the received signal. No connection is made to a reflector. It is usually spaced away at one-quarter wavelength for the desired signal.

Relaxation Oscillator. A relaxation oscillator is a generator of electric current waves whose amplitudes vary between negative cutoff and poitive overload, as limits. In essence, a relaxation oscillator is a violently regenerative device for which many circuit arrangements exist in practice.

Retrace. The return path of the electron beam as it is swept back across the raster on the cathode-ray tube face after the completion of each scanning line and field trace.

RC Circuit. This refers to a time-determining network composed of resistors and capacitors in which the time constant is the product of resistance by capacitance.

Resolution. That quality of a television image which enables an observer to distinguish fine detail.

Resolution Chart. A test pattern containing a number of converging lines. The point on the screen where these lines seem to merge into one, determines the maximum resolution of the image. Resolution is normally indicated as the number of lines which can be distinguished as individual.

Return Time. This is the time required for retrace or flyback of the electron beam at the end of the scanning of the raster.

RF Response. This refers to the wide-band acceptance of signals in a television receiver and defines the selectivity for signals lying outside of the channel being received.

Retrace Ghost. An image produced during the retrace period. It may be due to improper blanking of the camera at the transmitter.

Return Period. The time required for the spot to return after each sweep. It is also referred to as return time.

Sawtooth. A voltage or current waveform which rises lineraly to its peak value and then drops rapidly back to its starting level. The sawtooth waveform is used extensively for sweep or scanning in oscilloscopes and television equipment. If the sawtooth is not linear, the spot will move across the fluorescent screen at a varying rate and the pattern will appear to be crowded toward one side.

Scanning. The process of exploring an image, usually with an electron beam, in a predetermined pattern. In standard television practice, scanning of an image is accomplished in 525 horizontal lines.

Scanning Spot. This refers to an electrical window which scans an image field. Usually it refers to the size of the cross section of an electron beam used in a television pickup tube. In the image dissector it refers to the size of the aperture across which the extended electron image is scanned.

Separator. A clipping circuit used to remove a portion of a waveform by virtue of its amplitude. In the television receiver, a separator circuit is used to extract the synchronizing pulses from the composite signal.

Second Anode. This usually refers in television practice to the highest potential connection of a cathode-ray tube. Connections to the second anode supply the power for giving the electron beam its final, high level of energy.

Secondary Electron. An electron which has been knocked out of the surface of a metal during bombardment by other electrons, called primary electrons.

Secondary Emission. This refers to the phenomenon of knocking secondary electrons out of a surface by means of bombarding that surface with primary electrons.

Serrated Vertical Pulses. The wide vertical synchronizing pulse is divided into a number of narrower pulses in order to prevent loss of horizontal synchronization during vertical flyback.

Series Peaking. The technique of introducing a peaking coil in series with a resistor as the plate load of a vacuum tube to produce peaking at some desired frequency in the pass band.

Serrated Signal. This consists of serrated pulses for field synchronizing, plus a preparatory period in which line-doubling pulses are inserted in order to pass the integrating circuit ahead of time to give equal peaks on alternate pulses.

Shunt Peaking. The use of a peaking coil in a parallel-circuit branch to feed signals from the output load of one vacuum tube to the input load of a following tube, for the same purpose as a series-peaking

circuit, but with the added advantage of splitting up the distributed capacitances of the two tubes.

Single Sideband. Transmission of a carrier and substantially only one sideband of modulation frequencies, usually the upper sideband in television practice.

Spectrum. The frequency band over which radiations are spread. It is usually used in connection with light frequencies, but may refer both to visible and invisible radiations.

Spot. This refers usually to the area on which an electron beam is focused.

Spot Size. This refers to the size of an electron beam.

Staggered Circuits. Circuits are said to be staggered when they are alternately tuned to two different frequencies, in order to obtain broad-band response. A complete stage of amplification in a staggered-circuit amplifier requires two vacuum tubes with output circuits tuned to different frequencies. The separation in frequency divided by the mean frequency of the two circuits is a coefficient of staggering and corresponds directly to coefficient of coupling in double-tuned circuits.

Staggered Tuning. Alignment of successive tuned circuits to slightly different frequencies in order to widen the over-all response.

Sweep. Movement of the spot across the screen of a cathode-ray tube. Sweep is normally accomplished either by applying a sawtooth voltage to the deflection plates (electrostatic deflection) or by passing a sawtooth current through the deflection coils (electromagnetic deflection).

Sync. This is an abbreviation for synchronization and applies to a timing signal for determining the point in time at which an electrical oscillation or process will start.

Synchronization. Timing of an electrical action or waveform. In the television receiver, the horizontal and vertical sweep oscillators are synchronized or locked-in by the synchronizing pulses which accompany the transmitted signal.

Synchronization Clipper. A circuit designed to remove the synchronizing pulses from the composite signal.

Synchronization Pulses. Pulses transmitted along with the picture information and used to lock the frequency of the sweep generators in the receiver.

Synchronization Separator. Same as synchronization clipper.

Tearing. Splitting of the television picture due to improper synchronization.

Test Pattern. A fixed television image used to determine the quality and correctness of adjustment of a television system. See Resolution Chart.

Time Constant. The time required in an electrical circuit for potential or current to rise to approximately 63% of its steady, final value or to fall to approximately 37% of its initial value.

Time Delay. The time lapse between an electrical occurrence at the start of a transmission and the reproduction of this occurrence

at a remote point.

Time-Determining Circuit. A circuit composed of energy-storage components having a time constant designed to introduce a predetermined amount of time delay.

Timer (Generator). An equipment designed to generate standard sync signals for synchronizing all components of deflection apparatus in a television system.

Trace. The path followed by the spot as it moves across the screen of a cathode ray tube.

Trap. A tuned circuit used to eliminate a given signal or to keep it out of a given circuit. For instance, in the television receiver, traps in the video circuits keep the sound signal out of the picture channel. One type of trap is simply a tuned circuit which absorbs the energy of the signal to be eliminated.

Transmission Band. This refers to the band of frequencies utilized for transmitting information electrically.

Transmission Line. A two-conductor circuit having uniform characteristics for transmitting electrical signals.

UHF Waves. This refers to carrier frequencies in the ultra-high frequency spectrum between 300mc and 3000mc.

Vertical. This refers to the dimension of height in the picture.

Vertical Blanking. The application of cutoff bias to the cathode-ray tube during the vertical retrace.

Vertical Centering Control. The adjustment which shifts the image in the vertical direction so that it may be centered on the screen.

Vertical Hold. The adjustment which varies the free-running frequency of the vertical sweep oscillator in the television receiver. When this adjustment is properly set, the incoming synchronizing pulses will "lock-in" the frequency of the vertical oscillator.

Vertical Resolution. This refers to the line structure of the image, that is the number of lines or picture elements which can be resolved in the vertical direction.

Vertical Retrace. The movement of the spot from the bottom of the image to the top after each vertical sweep. The cathode-ray tube is biased beyond cutoff during this time.

Vertical Synchronization. Locking in of the vertical sweep oscillator by the incoming vertical synchronizing pulses. (See Vertical Hold).

Vestigial-Sideband Transmission. A method of transmission in which one set of sidebands, is largely, but not completely, eliminated. This system is employed in commercial television practice.

Video Amplifier. The amplifier stages following the video detector in a television receiver. They are designed to have a flat response up to several megacycles.

Video Detector. The demodulator circuit which extracts the picture information from the modulated carrier.

Video Signal. This refers to a time sequence of electrical pulses generated at the signal plate of a television pickup tube.

APPENDIX

Video Waveform. This refers to the portion of the waveform which corresponds to the light and dark values in the picture as they are transformed into an electrical signal, but does not include the synchronizing waveform.

Viewing Distance. This refers to the best distance to view a television picture from the standpoint of seeing all the detail which the picture is capable of resolving.

Visible Spectrum. That portion of the spectrum of electromagnetic radiations which is visible to the human eye.

Wave-Shaping Circuit. A circuit which alters the form of an electric wave to a different form.

Wedge. A convergent pattern of black-and-white lines equally spaced, and used as a television test pattern.

Width. The horizontal dimension of the television image.

Width Control. The adjustment which varies the horizontal size of the television picture. This is accomplished by controlling the amplitude of the horizontal sawtooth.

Yoke. An arrangement of deflection coils, usually including two sets of two coils each, for producing the magnetic deflection field for the electron beam in a cathode-ray tube.

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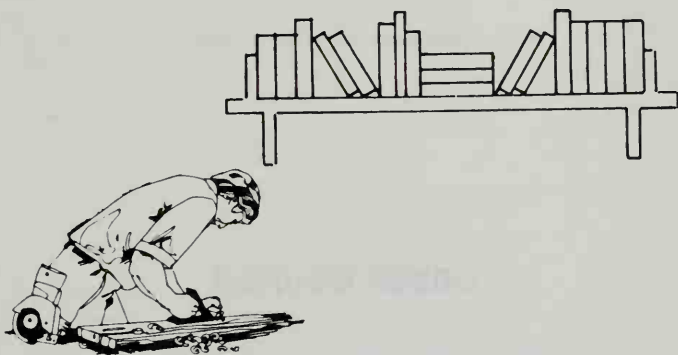
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